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Infestation of Grasses of the Genus *Aegilops* by the Hessian Fly

ELMER T. JONES, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Grasses belonging to the genus *Aegilops*, commonly called goat grass, recently have been observed to support appreciable infestations of the hessian fly, *Phytophaga destructor* (Say), in Kansas. The purpose of this paper is to record this fact and to show the apparent variation in susceptibility to fly infestation among these species.

The species of *Aegilops* are of recent introduction into the United States. The three species known to occur in the United States as weeds in fields and pastures are *A. cylindrica*, *A. ovata* and *A. triuncialis*.

Johnston (1931) and Hitchcock (1935) report *A. cylindrica* to be a noxious weed in wheat fields in Kansas and several adjoining States. In this area *A. cylindrica* is a winter annual. The seeds germinate with winter wheat in the fall, and the plants compete with wheat throughout the growing season, producing seed which disarticulates and drops to the ground when the wheat is harvested, thus seeding a crop for the next season.

A. ovata and *A. triuncialis* do not now occur generally in wheat fields. However, since these and a number of other species of *Aegilops* that have been tested appear to be similar to *A. cylindirca* in life habit, adaptation, competition and mode of dissemination, it is probable that they also will eventually become established in wheat fields as weeds, and, as such, some species may maintain and carry over infestations of the hessian fly, thereby complicating its control.

AEGILOPS CYLINDRICA.—Field observations extending over several years, tests in small plats with caged flies, and numerous flat and pot tests under severe artificial infestations of eggs of flies bred from wheat indicate that *A. cylindrica* taken from fields in central Kansas is extremely resistant to the development of hessian fly larvae. In the rare cases where larvae have developed on this strain of *A. cylindrica* the puparia have been indistinguishable from puparia produced on wheat plants.

Observations made in the field and in small test plots indicate that *A. cylindrica* is considerably less attractive than wheat for oviposition by the hessian fly. This difference, however, has been less marked in greenhouse and hotbed tests than in the field.

RELATIVE ATTRACTIVENESS FOR OVIPOSITION.—Results of a greenhouse test to determine the relative attractiveness of strains of *Aegilops* are shown in table 1. In general these data, obtained by infesting 3 potted replications of each of the 15 grass strains and 2 wheat checks under a single cage, show no outstanding tendency of the flies to oviposit on particular

Table 1.—Comparative attractiveness of strains of *Aegilops* for oviposition by the hessian fly as indicated by number of eggs deposited.

STRAINS	NUMBER OF PLANTS IN TEST WITH EGGS	AVERAGE NUMBER OF LEAVES PER PLANT	AVERAGE NUMBER OF EGGS PER LEAF
GRASS STRAINS			
A. ovata (Wn. 2477)	27	3.9	5.1
A. squarrosa (Bruner)	36	2.3	5.5
A. crassa rubignosa	27	2.8	5.5
A. trioristata (GH 1934)	23	4.2	5.5
A. crassa rubescens	19	3.0	6.0
A. ovata (Kans. glabrous)	20	5.0	6.0
A. cylindrica (Wn. 2433)	27	2.6	6.3
A. ventricosa (France)	35	3.0	6.6
A. triuncialis (Wn. 2484)	23	3.5	6.7
A. ovata globosa	25	3.6	7.6
A. ventricosa	20	3.3	8.0
A. triuncialis (Tiflis)	24	3.4	8.1
A. triuncialis (Kans. pubescent)	24	3.9	8.5
A. cylindrica (glabrous)	17	2.6	8.5
A. cylindrica rubignosa	18	3.4	9.4
WHEAT CHECKS			
Marquillo	43	3.3	14.7
Ceres	41	2.8	21.4

strains. However, it may be noted that *A. ventricosa*, *A. triuncialis* and *A. cylindrica* generally received more eggs per leaf than did other species. In this test all plants received eggs.

The number of eggs shown for Marquillo and Ceres is somewhat less than the number actually deposited, as portions of leaves with concentrated masses of eggs were removed and discarded prior to the counting. However, the data show distinct oviposition preference for wheat.

FIG. 1.—Spikes of several species of *Aegilops*, reading from left to right as follows: (a) *A. crassa rubignosa;* (b) *A. crassa rubescens;* (c) *A. cylindrica* (pubescent); (d) *A. cylindrica rubignosa;* (e) *A. squarrosa;* (f) *A. ventricosa;* (g) *A. triuncialis;* (h) *A. triuncialis* (Kans. pubescent); (i) *A. ovata* (glabrous); (j) *A. trioristata;* (k) *A. ovata globosa.*

COMPARATIVE SUSCEPTIBILITY OF STRAINS.—Twenty-two strains representing 11 species of *Aegilops* were tested in the greenhouse for reaction to infestation. All seed, except one strain of *A. cylindrica* from Pratt, Kans., was supplied by C. O. Johnston of the Bureau of Plant Industry, United States Department of Agriculture, from leaf-rust test material.

Plants growing in 3-inch pots were tested in triplicate series in flats filled with sand. They were exposed to flies under cheesecloth-covered cages. When sufficient eggs had been deposited, puparia and cage were removed. Eggs on the upper side of leaves were counted. In some cases parts of leaves covered with masses of eggs were removed and discarded to facilitate counting. The removal of the excess eggs, however, should have no bearing on the final results, as only a limited number of larvae can develop on small plants.

Characteristic heads of several species tested are shown in fig. 1, and typical injury caused by larvae is shown in fig. 2.

After the egg count had been completed, time was allowed for incubation. Although counts of unhatched eggs were not made, observation indicated a uniformly normal hatch on all plants. Following completion of larval development, the plants were dissected to determine infestation.

In table 2 it may be noted that strains of *A. cylindrica* and *A. ventricosa* appear to be more resistant to the development of hessian fly larvae than any of the other species in the test. The data also show that strains of the same species differ widely in reaction to infestation. This is emphasized in the case of *A. cylindrica* from Pratt, Kans., with zero infestation and *A. cylindrica rubignosa* with 53 per cent of the plants infested. Similar wide differences are also apparent in several other species.

Ability of plants of some strains to recover from infestation injury was one of the outstanding features of the test. In some cases this was due to prolific tillering of infested plants.

In strains of *A. cylindrica*, *A. ventricosa* and *A. triuncialis*, however, some heavily infested stems were not injured by infestation, while stems of other strains were severely injured or killed.

A number of plants in the Marquillo wheat checks recovered from injury by tillering. Plants of the Ceres checks were severely injured or killed. The fly-free stems of the infested Marquillo plants were discolored and otherwise affected by infestation. As a rule, the fly-free stems of infested *Aegilops* plants gave no outward indication of infestation. Apparently the feeding larvae are more harmful to the tissues of wheat than to those of *Aegilops*.

INFESTATION REACTION OF *AEGILOPS*-

FIG. 2.—Comparative injury to *Aegilops* and wheat plants caused by hessian fly larvae, reading from left to right as follows: (a) *Aegilops cylindrica;* (b) Marquillo (check); (c) Ceres (check); (d) *A. triuncialis* by *Triticum durum.*

Table 2.—Summary of results. Infestation of strains of *Aegilops* by the hessian fly.

STRAIN	NUMBER OF PLANTS INFESTED WITH EGGS	PER CENT INFESTED WITH PUPARIA		PUPARIA		EGGS		AVERAGE PER CENT OF EGGS PRODUCING PUPARIA	REMARKS
		Plants	Stems	Total	Average Number per Infested Plant	Total Number on Plants	Average Number per Plant		
GRASS STRAINS									
A. ventricosa (France)	35	0.0	0.0	0	0.0	702	19.5	0.0	No injury.
A. cylindrica (Pratt, Kans.)	23	0.0	0.0	0	0.0	371	16.1	0.0	No injury.
A. cylindrica (5-2-glabrous)	15	6.7	4.0	1	1.0	398	26.0	0.25	No injury.
A. ventricosa	20	10.0	9.0	4	2.0	517	26.0	0.8	No injury.
A. cylindrica (Wn. 2433)	24	21.0	15.0	9	1.8	396	16.5	2.3	Very slight injury. Infested plants have wider leaves.
A. crassa rubignosa	28	29.0	19.0	24	3.0	429	15.2	5.6	Infested plants dead, others normal.
A. trioristata (ss vecta)	17	29.4	8.6	11	2.2	566	33.5	2.0	No injury apparent.
A. tauchii (PQ 77691)	25	32.0	19.0	14	1.8	208	8.3	6.2	Infested plants severely injured. All plants very small.
A. ovata (Wn. 2477)	27	48.0	25.0	32	2.5	525	19.5	6.1	No injury apparent.
A. bicornis	19	53.0	31.0	20	2.0	149	7.9	13.5	Moderate to slight injury.
A. cylindrica rubignosa	17	53.0	26.0	37	4.1	651	39.0	5.5	Good recovery from injury.
A. crassa rubescens	18	56.0	42.0	63	6.3	320	17.8	19.5	Serious injury.
A. triuncialis (Wn. 2484)	23	57.0	35.0	66	5.1	545	24.0	12.1	Some injury but good recovery.
A. triuncialis nigro albescens	31	61.3	45.0	56	3.0	373	12.0	15.0	Moderate injury.
A. squarrosa (Bruner)	32	63.0	54.0	42	2.1	461	14.5	8.9	Very small plants, moderate injury.
A. biuncialis	20	65.0	23.0	36	2.8	276	13.8	13.0	Infested plants seriously injured.
A. columnaris	20	65.0	33.0	29	2.2	249	12.4	11.7	Moderate to severe injury.
A. ovata (Kans. glabrous)	18	67.0	31.0	50	4.2	556	61.0	9.0	Moderate injury. A number of dead larvae found.
A. trioristata (GH 1934)	22	68.0	41.0	43	2.9	513	23.0	8.3	Uniformly severe injury, good recovery.
A. triuncialis (Kans. pubescent)	20	70.0	52.0	68	4.8	729	36.5	9.3	Severe injury.
A. triuncialis (Tiflis)	22	73.0	49.0	61	3.8	602	27.5	10.0	Severe injury, good recovery.
A. ovata globosa	21	76.0	35.0	72	4.5	561	26.6	12.9	Severe injury, good recovery.
WHEAT CHECKS									
Marquillo	50	72.0	34.0	268	7.5	2000	40.0	7.5	Severely injured plants, fair recovery.
Ceres	55	88.0	64.0	312	6.5	2634	48.0	9.0	Many dead plants. Very severe injury. Puparia small due to crowding.

WHEAT HYBRIDS.—Infestation reaction of *Aegilops*-wheat hybrids obtained from W. J. Sando, Bureau of Plant Industry, U. S. Department of Agriculture, has been studied briefly. Plants of the two lots of seed were comparably tested in the greenhouse in the same manner as

SUMMARY.—In greenhouse tests of 22 strains representing 11 species of *Aegilops*, 18 strains were found susceptible to hessian fly infestation. Two strains each of *A. ventricosa* and *A. cylindrica* appeared to be resistant to fly infestation. All strains of *Aegilops* were found to be

Table 3.—Summary of results. Infestation of wheat-*Aegilops* crosses by the hessian fly.

STRAIN	PUPARIA				EGGS				REMARKS
	PER CENT INFESTED WITH PUPARIA		Total	Average Number of Puparia per Infested Plant	Number of Plants Infested	Total Number on Plants	Average Number per Plant	Per Cent Producing Puparia	
	Plants	Stems							
F⁴ WHEAT-AEGILOPS HYBRIDS									
A. triuncialis×Purple-seed *T. durum*, Sel. 3	67	33	8	4	3	100	33	8	Infested stem dead, others healthy.
A. triuncialis×Purple-seeded *T. durum*, Sel. 4	67	40	9	4.5	3	117	39	7.7	Moderate injury.
A. triuncialis×Purple-seeded *T. durum*, Sel. 5	33	17	8	8	3	121	43	6.6	Segregating? Serious injury to infested plant.
A. triuncialis×Purple-seeded *T. durum*, Sel. 6	100	25	11	11	1	50	50	22	Plant very healthy. No sign of injury although 11 large puparia were removed from sheath.
A. triuncialis×Purple-seeded *T. durum*, Sel. 8	0	0	0	0	3	85	28	0	Resistant.
WHEAT CHECKS									
Marquillo	35	32	22	3.7	17	125	7	17.5	Severe injury to infested plants.
Ceres	71	52	69	4	24	694	29	10	Too many eggs. Many unrecognizable larvae. Majority of plants killed.
F⁶ WHEAT-AEGILOPS HYBRIDS									
A. triuncialis×*T. durum* (var. Pelis)	0	0	0	0	13	212	16	0	Harsh tissues, very poor plants resembling *Aegilops* more than wheat.
A. ovata×*T. dicoccum* (Black W. Emmer)	71	53	56	4	14	215	15.5	26	All infested plants show severe injury. Soft tissues.
A. ventricosa×*T. turgidum* (var. Alaska)	90	77	37	6	29	511	17.5	7.3	Soft tissues. Serious injury to a few plants, others recovered.
A. triuncialis×*T. turgidum* (var. Alaska)	100	100	37	3.4	11	249	22.6	15	Soft tissues. Serious injury to all plants.
WHEAT CHECKS									
Marquillo	39	33	38	3.8	26	713	27	4.8	Moderate injury.
Ceres	93	93	79	5.9	30	726	24	11	Serious injury. Too many eggs for uniform development.

the aforementioned species of *Aegilops*. One lot consisted of F⁴ plants from five selections of *A. triuncialis*×purple-seeded *Triticum durum*. The other lot consisted of F⁶ plants of selections from the crosses *A. triuncialis*×*T. durum*, *A. triuncialis*×*T. turgidum*, *A. ovata*×*T. dicoccum* and *A. ventricosa*×*T. turgidum*. The results of these tests are given in table 3.

Only two crosses were found resistant to the hessian fly, *viz.*, *A. triuncialis*×*T. durum* (var. *Pelis*) and selection 8 of *A. triuncialis*×purple-seeded *T. durum*. Plants of selection 5 of *A. triuncialis*×purple-seeded *T. durum* were segregating for resistance. The remaining crosses were susceptible to infestation.

much less attractive to flies for oviposition than was wheat. Egg counts showed that comparably infested plants of 15 strains of *Aegilops* differed in attractiveness for oviposition, but no outstanding differences between strains were noted.

Tests of nine selections of wheat-*Aegilops* crosses of F⁴ and F⁶ generations gave infestations of 0 to 100 per cent.

Aegilops cylindrica and *A. ventricosa* are possible sources of resistant parent material for breeding fly-resistant wheat. Susceptible strains of *Aegilops* are potential secondary hosts which may at some future time have to be reckoned with in the prevention of damage by the hessian fly.—1-7-38.

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Comparative Resistance to the European Corn Borer of Two Hybrid Strains of Field Corn at Toledo, Ohio

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Incident to the testing of the corn borer resistance of numerous hybrid strains of field corn by the Bureau of Entomology and Plant Quarantine of the U. S. Department of Agriculture, an opportunity for a direct comparison between a previously reported borer-resistant strain and a standard borer-susceptible strain was provided in the tests made in 1936 and 1937.

CORN VARIETIES USED.—Michigan Hybrid No. 561 has been reported by Marston (1936) to be resistant to the European corn borer, *Pyrausta nubialis* (Hbn.). This hybrid is described as a "top-cross between a synthetic variety, S-10, and an inbred strain. S-10 was made by blending 91 inbreds. All of these inbreds and also the inbred used in top-crossing S-10 have Maize Amargo breeding and have shown strong indications of being resistant to borer attack. S-10, the synthetic hybrid, likewise has shown under tests marked resistance to the borer. The inbred used to sire S-10 in producing Hybrid No. 561 has shown distinct resistance to borer attack for several years."

The single cross A×Tr has been used since 1933 in the tests at Toledo, Ohio, as a standard borer-susceptible strain for the comparison of other strains of field corn. This use was based on the fact that A×Tr appears to offer the borers a maximum chance for survival under a given set of conditions. The number of borers surviving on it have about equaled those surviving on the locally adapted varieties Clarage and Woodburn. The data on this point are presented in table 1. Eight plantings of A×Tr have averaged 8.18 mature borers per plant from a given

Table 1.—Numbers of European corn borers per plant resulting from given numbers of egg masses hatching on single cross A×Tr and the local varieties Clarage and Woodburn, near Toledo, Ohio, 1933, 1934 and 1935.

DATE OF PLANTING	STRAIN OF CORN A×Tr		Clarage		Woodburn	
	Number of Borers per Plant	Mean Number of Days from June 30 to Tassel Appearance	Number of Borers per Plant	Mean Number of Days from June 30 to Tassel Appearance	Number of Borers per Plant	Mean Number of Days from June 30 to Tassel Appearance
May 19, 1933	9.8	17.4	10.0	14.3	—	—
June 2, 1933	6.4	24.3	6.5	23.2	—	—
May 3, 1934	9.3	4.4	9.6	6.0	9.2	7.3
May 17, 1934	6.8	14.7	6.7	15.0	6.4	17.3
May 31, 1934	4.2	22.9	3.7	24.0	4.8	25.3
May 11, 1935	15.0	21.4	15.1	17.1	13.9	19.9
May 27, 1935	8.6	25.0	10.5	23.0	8.0	24.6
June 11, 1935	5.3	32.7	5.9	30.7	4.4	32.1
Mean	8.18	20.4	8.5	19.2	7.78	21.1

* The authors gratefully acknowledge their indebtedness to W. A. Baker under whose general supervision these tests were made possible and conducted, to A. R. Marston for supplying seed of the Michigan strains, and to Ralph Mathes for providing egg masses of the European corn borer moth in 1937.

number of eggs compared with 8.50 borers in Clarage. Six plantings of A×Tr have averaged 8.20 borers per plant compared with 8.58 borers in Clarage and 7.78 borers in Woodburn. Strain A×Tr averaged a day later in maturity than Clarage and a day earlier than Woodburn. Strain A×Tr has averaged only 1.2 days earlier than Michigan Hybrid No. 561, table 2. It would seem, therefore, that A×Tr should be a good of the same yielding capacity. Michigan Hybrid No. 561 was given all these tests.

TEST FOR RESISTANCE TO BORER SURVIVAL.—Corn borer infestations were induced by placing by hand an equal number of egg masses on each plant. The egg masses were produced in the laboratory by the method described by Patch and Peirce (1933), with some modifications. The relative periods required for maturity of the strains were measured by

Table 2.—Numbers of European corn borers per plant resulting from given numbers of egg masses hatching on Michigan Hybrid No. 561 and single cross A×Tr, near Toledo, Ohio, 1936 and 1937. Average of 20 to 48 plants.

Date of Planting	Date Borers Hatched	Number of Borers per Plant		Average Occurrence of the Following Phases of Maturity: Days From June 30 to Indicated Phase for		Difference in Days*	Phases
		Strain Mich. 561	Strain A×Tr	Strain Mich. 561	Strain A×Tr		
May 21, 1936	July 9	8.6	8.7	21.1	20.7	0.4	Tassels visible
	July 13	8.3	7.4	21.2	20.1	1.1	Tassels visible
	July 15	6.9	8.5	23.1	19.7	3.4	Tassels visible
	July 17	6.7	10.8	23.5	21.0	2.5	Tassels visible
	July 20	15.2	14.7	22.3	19.6	2.7	Tassels visible
May 22, 1936	July 16	7.8	7.3	33.0	32.0	1.0	Silking
May 20, 1937	July 8	2.1	2.6	31.3	32.3	−1.0	Pollen shedding
	July 9	3.7	5.0	30.4	30.0	.4	Pollen shedding
	July 10	4.3	3.7	30.9	29.9	1.0	Pollen shedding
	July 12	5.9	8.1	28.0	27.9	.1	Pollen shedding
Average		*6.95*	*7.68*			*1.16*	

* Strain A×Tr was the earlier except for the record indicated by a minus sign.

strain to compare for borer resistance with Michigan No. 561.

Strains A×Tr, Clarage and Woodburn, have about the same seasonal requirements, and approximately the same number of borers were observed to survive on them. Hence, if other strains of about the same maturity as A×Tr are found to mature as many borers, from an equal number of eggs, as A×Tr, it may be concluded that those strains are no more resistant to the survival of the borer than the locally adapted varieties. If, however, strains are found apparently not resistant to the establishment or survival of the borer on them, they might actually be borer resistant owing to their lack of attractiveness to the moths for egg deposition. Again, such strains might be borer resistant or borer tolerant in the sense that a given number of borers would have less effect in reducing their yield than the yield of less tolerant strains

the time when the tassels or silks first became visible or by the time when pollen shedding first occurred. The date of either of these events, according to the experiment, was recorded for each plant in the sample and the mean date for the strain determined. Before the migration of the full-fed borers was in active progress, all plants of a given sample were dissected to determine the number of mature borers. The plant samples in 1936 consisted of 20 to 24 plants, but in 1937 the samples of strain A×Tr were twice as large. In 1936 the corresponding samples of the two strains were adjacent; and in 1937 each sample consisted of two replicated plots, 2 by 2 hills in size, distributed at random among 38 other strains. The mean number of borers per plant and the date when the tassels, silks or pollen shedding was first observed are given in table 2 for each of 10 tests.

The results given in table 2 show that nearly as many borers survived in Michigan No. 561 as in the borer-susceptible strain A×Tr. There was an average of 0.73 of a borer more in A×Tr, but a fraction of this difference might have been due to the slightly more advanced stage of the plants.

Seed of synthetic variety S-10 and of the inbred Michigan 1450, with which it was crossed to produce the top-cross Michigan No. 561, was provided in 1937 for planting with 20 inbreds in a borer-resistance test of inbreds. All the plants in each of the five replications provided were infested with three egg masses per plant on the same date. Averages of 5.0 ± 0.54 and 5.6 ± 0.63 borers per plant were dissected from 52 plants each of S-10 and inbred Michigan 1450, respectively. On the basis of the regression of the borers per plant on the dates of pollen shedding of the 22 strains, the numbers of borers expected from these two strains were 5.9 and 5.2 per plant, respectively. The data indicate that the borer population both in inbred Michigan 1450 and in S-10 was not significantly different from the number expected.

TEST FOR RESISTANCE TO EGG DEPOSITION.—In a planting made in 1937, four rows, 50 hills in length, of A×Tr were followed by four rows of Michigan No. 561. One tagged plant from each of 50 hills of A×Tr, in the row adjacent to Michigan No. 561, was examined for egg masses at least once in every five days throughout the oviposition period. Likewise a sample of plants of Michigan No. 561 was examined in the row adjacent to A×Tr. The height of each of the tagged plants to the highest tip of the leaves, extended straight up, was measured on July 8 to the nearest centimeter.

If each egg mass laid may be considered as representing a choice by the moths between the plant where the mass was found and the plant in the opposite hill, the moths chose 39 times between Michigan No. 561 and A×Tr. Michigan No. 561 was chosen 23 times and A×Tr 16 times. The averages heights of the plants of Michigan No. 561 and A×Tr in the 39 choices were 131.1 and 116.7 cm., respectively.

In addition to the comparison between Michigan No. 561 and A×Tr, a comparison was made between Michigan No. 561 and single-cross R4×Hy. This test was made in exactly the same manner as the test just discussed. In this test the moths chose 35 times between Michigan No. 561 and R4×Hy. Michigan No. 561 was chosen 26 times and R4×Hy 9 times. The average heights of the plants of Michigan No. 561 and R4×Hy in the 35 choices were 135.4 and 115.2 cm., respectively.

In the comparison between Michigan No. 561 and A×Tr, 59 per cent of the total number of egg masses was laid on Michigan No. 561, this strain being 14.4 cm. taller. In the comparison between Michigan No. 561 and R4×Hy, 74 per cent of the total number of egg masses was laid on Michigan No. 561. In this case Michigan No. 561 was taller by 20.2 cm. Height probably was a factor in the greater number of egg masses laid on Michigan No. 561.

TEST FOR RESISTANCE TO REDUCTION IN YIELD.—Three 5-by-10-hill plots of Michigan No. 561 were planted on uniform land on May 22, 1936. The plants in the first plot were subject only to the oviposition of the moths in nature. Each plant in the next adjacent plot was infested with three egg masses and each plant in the next plot was infested with five egg masses. There resulted 0.6, 6.6 and 8.9 borers per plant. The yield of the plants remaining, after the samples had been dissected to determine the number of borers, was at the rate of 54.3, 43.4 and 39.3 bushels per acre of 15.5 per cent moisture content. The method of least squares was used to determine the regression of the yield on the borer population and to estimate the yield that would have been obtained in the absence of borers. The yield was reduced at the rate of 1.81 ± 0.023 bushels per acre per borer per plant. The yield in the absence of borers was estimated to be 55.4 bushels.

The locally adapted Clarage strain of corn has been tested on seven plantings from 1929 to 1932, inclusive. The rate of reduction in yield of this strain was found to be 1.83 ± 0.064 bushels per borer per plant from a normal yield, in the absence of borers, of 54.8 bushels. The yield of Michigan No. 561 does not appear, from the test given it, to be reduced by the corn borer less than would be expected of the Clarage strain.

SUMMARY.—Field experiments carried on in 1936 and 1937 under the direction

of the laboratory at Toledo, Ohio, included the top-crossed hybrid field-corn strain Michigan Hybrid No. 561. This strain has been reported to be resistant to the European corn borer. In comparison with standard strains of about equal seasonal requirements known to possess no inherent resistance to the corn borer, and tested by proved methods of inducing infestations by hand, Michigan No. 561 was found not to be relatively borer resistant with respect to the number of mature borers surviving from a given number of eggs. In other experiments Michigan No. 561 was found not to be borer resistant with respect to the deposition of eggs by the moths in nature, nor to the reduction in the yield of grain by a given number of borers compared with the reduction that was expected of strains of equal yielding capacity.—1-7-38.

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The Annual White Grub, *Ochrosidia villosa* Burm., in Ohio Lawns

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During the past three or four years white grubs have severely injured lawns at many points in Ohio. The damage has been most severe in the eastern part of the State. Reared adults of the dominant species involved have been identified by E. A. Chapin of the U. S. National Museum as *Ochrosidia villosa* Burm. The grubs of this genus can be distinguished from those of the genus *Phyllophaga* by the absence of the two median longitudinal rows of mesad-pointing spines on the last abdominal segment and also by a transverse anal slit which in the *Phyllophaga* is V-shaped. These differences were pointed out specifically by Hayes (1918).

In some lawns examined the grub population was a mixture of *Ochrosidia villosa* and members of the genus *Phyllophaga* but in many instances little else than the former species was found. In some lawns, as many as 47 grubs per square foot were observed and in many instances populations of 10 to 15 grubs per square foot occurred. Such populations practically destroyed the grass, as fig. 1 shows.

The grubs of this species seem to burrow through the soil more extensively than do those of *Phyllophaga*. Under conditions of a severe infestation the soil is pulverized and the turf feels soft and springy to the step.

LIFE HISTORY.—As the name indicates, the annual white grub completes its life cycle in one year. The egg deposition period extends through late June and July. Observations to date indicate that for the most part eggs are deposited in grasslands in a manner similar to that of the *Phyllophaga*. After a period of 19 days the eggs hatch and the young grubs start feeding. They grow rapidly and by the approach of cold weather are nearly full grown. About the middle of October they begin migrating downward and spend the winter at a depth of 14 to 16 inches in the soil. Early in April they again start toward the surface. By May 1 most of the grubs are at the soil surface feeding on the roots of grasses. In table 1 is given the average depth of grubs for different periods in the fall of 1936, together with the mean air temperatures for the period. The record is based on the observation of 30 to 70 grubs at each period. Table 2 gives a similar record for the spring of 1937.

It may be noted from table 1 that the grubs started migration downward by October 26 and became stationary about the middle of November. In the spring

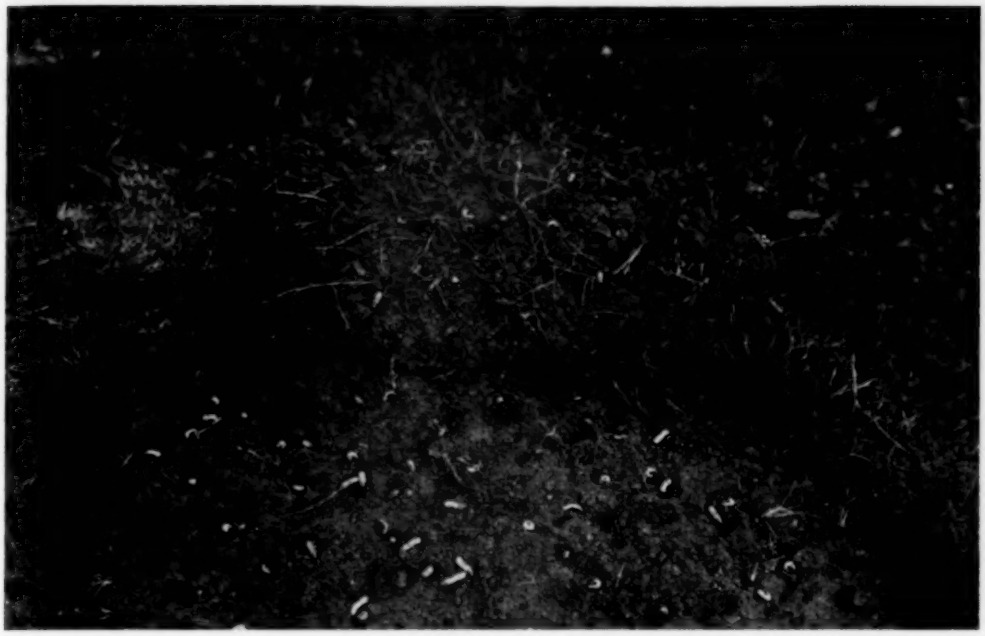

FIG. 1.—Sod of dead lawn turned back to show grub population and pulverized condition of soil.

they started up by April 9 and were all at the surface on May 11. By June 4 they again started a migration downward. The greatest mean depth for this period was attained by June 15. This movement was followed by pupation. The average depth of all pupae taken from the soil through this period was 6.4 inches. An average of 18.7 days was spent in the pupal period.

The adults begin emerging during the latter part of June, although a few individuals have occurred in light traps at Wooster as early as June 13. They continue in flight until the latter part of July. Of 69 adults reared from grubs in 1937, 59 per cent were males and 41 per cent were females.

Table 1.—Mean depth of grubs in the soil from October 6 to December 10, 1936.

DATE	AVERAGE DEPTH IN INCHES	MEAN AIR TEMPERATURE IN DEGREES F.
October 6	1.8	61.2
October 14	1.9	53.8
October 21	2.6	53.3
October 30	6.1	44.3
November 6	11.3	41.0
November 13	13.2	38.1
December 10	13.6	32.4

During the season of 1937, 10 light traps were operated at various points in the state. The adults, particularly the males, are very strongly attracted to lights; as many as a quart have been taken in a single trap in one night during the maximum flight period. As a result of the trapping program, large numbers were taken in the eastern part of the state; none, in the northwestern part, namely, at Holgate, Ada or McGuffey; and only a few at Mount Healthy, in the southwestern part. They were particularly abundant at Marietta, where a total of

Table 2.—Mean depth of grubs in the soil from April 1 to June 15, 1937.

DATE	AVERAGE DEPTH IN INCHES	MEAN AIR TEMPERATURE IN DEGREES F.
April 1	16.0	31.1
April 9	11.3	45.9
April 16	10.8	43.6
April 24	4.9	52.8
May 1	3.3	49.5
May 7	2.9	56.0
May 11	1.3	51.2
May 28	1.3	66.7
June 4	4.5	68.6
June 12	6.6	65.9
June 15	7.1	67.7

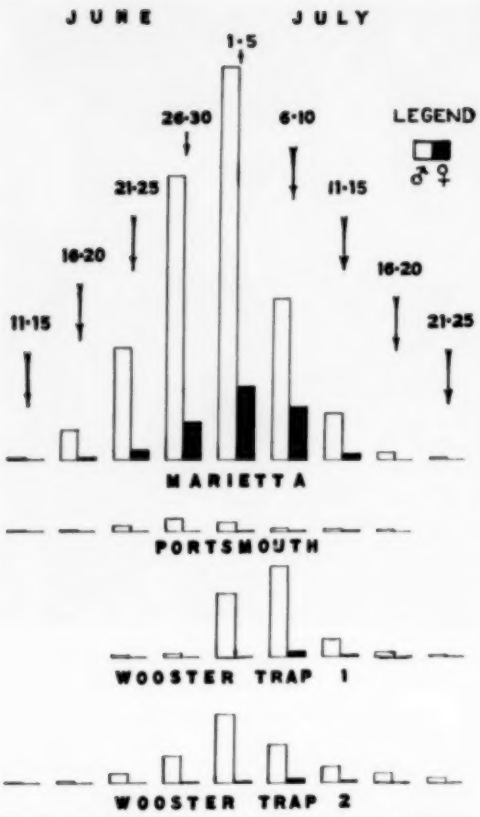

FIG. 2.—Seasonal distribution of beetle collections made from four lantern traps. The highest column in the Marietta record represents 4,178 individuals. All diagrams are made to the same scale.

11,312 males and 2,015 females was taken during the season.

Of the total number collected at all traps operated, the males exceeded the females in the ratio of 7 to 1. The sex ratio varied extremely, however, for different nights in any one area. For instance, in the Marietta trap there were 260 males and 306 females on June 26; 883 males and 3 females on June 29; 945 males and 3 females on July 2; and 972 males and 311 females on July 4. At present the writer is unable to give any explanation for these interesting variations. The differences suggest the need for a careful study of ecological and meteorological factors.

In fig. 2 the seasonal capture of both males and females is shown for four of the traps operated. The no. 1 trap at Wooster was located in the Station arboretum and was adjacent to wooded areas having a bluegrass cover. The no. 2 trap was located in an open area and probably drew beetles from various sodded regions, including lawns. It may be noted that the collection from the wooded area was about 5 days later than the one in the open field. It may be noted also that the more southerly Marietta and Portsmouth collections were somewhat earlier than either of the Wooster collections.

A food-host of the adult has not been found although many plants have been examined at night in the search. Even during the maximum flight period the only place beetles could be found in significant numbers aside from at lights was in infested lawns and even there they were not abundant and were not observed to be feeding. Females were frequently seen perched at the tip of a blade of grass but upon being disturbed by a flashlight they would leave the grass and start burrowing into the soil.

The complete seasonal history for the

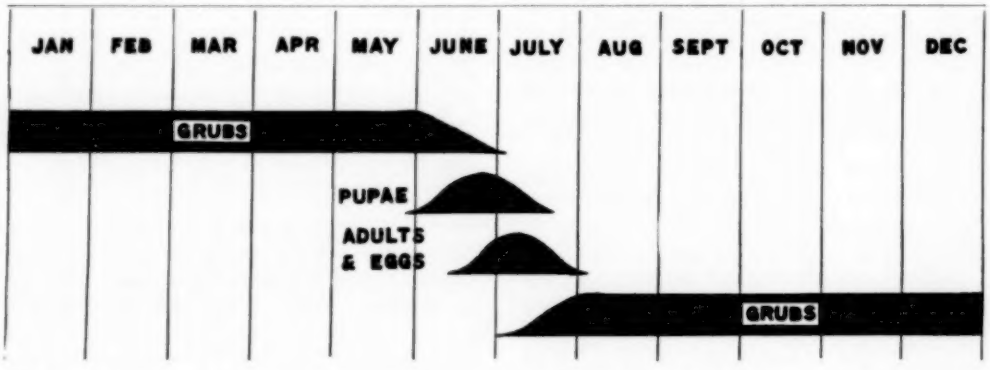

FIG. 3.—Diagram showing the seasonal occurrence of the various stages of *Ochrosidia villosa* Burm.

insect in the Wooster area is shown in fig. 3.

CONTROL EXPERIMENTS.—In order to provide fairly uniform conditions for an insecticide experiment, grubs of this species were collected and placed in the soil within 20-inch diameter sewer tile 16 inches long set upright in the ground, as shown in fig. 4. A disk of 18-mesh wire cloth was fitted into the bottom of each tile to prevent escape of the grubs. Twenty-five tiles were prepared in this manner and 20 grubs were placed in each. This provided 25 experimental units which were used for five treatments, each replicated five times. The upper six inches of soil in the tile consisted of screened compost in which small clumps of living bluegrass were planted for food. The grubs were placed in the compost and covered with a layer of the same material, in which the grass was planted.

The grubs were left undisturbed for a few days in order to permit them to become adjusted to their new environment. When they were found to be feeding normally, the following treatments were applied:

A.—Carbon disulfide plus rosin fish oil soap emulsion. This was made according to the Japanese beetle formula and consisted of a stock emulsion made up of 1 part rosin fish oil soap, 3 parts water, and 10 parts carbon disulfide. The stock emulsion was diluted at the rate of 1 quart to 50 gallons of water. This was applied at the rate of 1½ gallons per square yard.

B.—Carbon disulfide emulsion prepared as in A but applied at the rate of 3 gallons per square yard.

C.—Carbon disulfide emulsion made by mixing 85 parts of carbon disulfide with 15 parts of Grasselli spreader and sticker and diluting at the rate of 1 quart to 50 gallons of water. This was applied at the rate of 1½ gallons per square yard.

D.—Carbon disulfide emulsion made as in C but applied at the rate of 3 gallons per square yard.

E.—Check. Not treated.

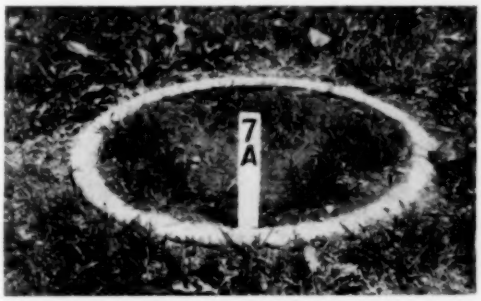

FIG. 4.—Buried sewer tile used for confining grubs in insecticide tests.

One hour after these treatments had been applied, water was added to all plots at the rate of 2 gallons per square yard. The insecticides and the water were applied by means of a sprinkling can. Five days later the soil was examined for grub mortality. Both live and dead grubs were recovered and counted. The results are given in table 3.

The analysis of variance on the data in this table indicates that a difference in means of 19.8 is required for significance at odds of 19 to 1. It may be noted that a mortality difference of 40 per cent was obtained in both types of emulsion when the application was increased from 1½ to 3 gallons per square yard. Both of the materials used made a satisfactory emulsion. When they were applied at the

Table 3.—Grub mortality after treatment with carbon disulfide emulsions.

TREATMENTS	RATE PER SQUARE YARD	PER CENT DEAD					
		Replication Number					Mean
		1	2	3	4	5	
A.—CS_2+soap emulsion	1½ gal.	40	67	46	72	75	60
B.—CS_2+soap emulsion	3 gal.	100	100	100	100	100	100
C.—CS_2+Grasselli spreader	1½ gal.	41	25	29	53	47	39
D.—CS_2+Grasselli spreader	3 gal.	100	95	65	47	88	79
E.—Check—not treated		0	0	0	15	5	4

higher rate without watering in an open-lawn test, slight injury occurred to white clover, but this was not apparent after a few days. However, 1.5 inches of rain fell between 8 and 10 hours after the insecticide application was made.

During the fall of 1937 a similar insecticide experiment was conducted, in which the following treatments were used. In this instance 25 grubs were placed in each tile.

A.—Lead arsenate, 5 pounds per 1000 square feet of surface, mixed with the upper layer of soil before the grubs were introduced.

B.—Lead arsenate, 5 pounds per 1000 square feet of surface, scattered over the soil surface after the grubs were in place.

C.—Lead arsenate, 10 pounds per 1000 square feet of surface, mixed with the upper layer of soil before the grubs were introduced.

D.—Lead arsenate, 10 pounds per 1000 square feet of surface, scattered over the soil surface after the grubs were in place.

E.—Carbon disulfide plus rosin fish oil soap emulsion applied at the rate of 3 gallons per square yard.

F.—Check. Not treated.

The arsenical treatments were applied on September 17 and the plots were immediately watered at the rate of approximately 2 gallons per square yard. The carbon disulfide emulsion was applied on September 27. The mortality record for all plots was taken on October 26. All of the soil in each tile was sifted, and the living grubs found therein were recorded. Live grubs only were counted in taking this record because many of the dead grubs had so thoroughly disintegrated that they could not be found. The survival record is given on table 4.

Table 4.—Grub survival record from insecticide test, 1937.

TREATMENTS	NUMBER OF GRUBS LIVING				
	Replication Number				Mean
	1	2	3	4	
A.—Lead arsenate, 5 lbs., mixed with soil	12	18	10	5	11.3
B.—Lead arsenate, 5 lbs., applied to surface	11	6	13	15	11.3
C.—Lead arsenate, 10 lbs., mixed with soil	6	10	9	7	8.0
D.—Lead arsenate, 10 lbs., applied to surface	5	4	16	5	7.5
E.—Carbon disulfide+ soap emulsion	5	3	0	2	2.5
F.—Check—not treated	19	22	19	20	20.0

In table 4 a difference in means of 6.6 is required for significance at odds of 19 to 1. It may be noted that the carbon disulfide plus soap emulsion again gave a high kill although not so high as in 1936. The lead arsenate treatments would probably have given higher kills than they did if the grubs had been actively feeding throughout the period. As shown in table 1, the grubs start moving downward about the middle of October. It is probable also that many of them were not feeding actively before that time. In spite of the higher mortality from the carbon disulfide treatment, the writer is inclined to favor the arsenical treatment because of the known residual effect of this material.—1-7-38.

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VIGOROUS MEASURES to standardize state plant quarantines of the region were undertaken by the Southern Plant Board at its meeting held at New Orleans, February 3 to 5. As an established policy, the Board reaffirmed its action taken at the San Antonio meeting in 1937 of disapproval of restrictions on incoming shipments of potential carriers of a given pest unless similar or parallel restrictions are imposed within the state issuing the order. A uniform draft of a sweetpotato weevil quarantine and eradication measures were approved to be put into effect by the various infested states. The states agreed to lift quarantines relating to the potato tuber moth, Japanese camphor scale, date-palm scale, strawberry pests and Colorado potato beetle; to revise and standardize quarantines relating to citrus canker, European corn borer and alfalfa weevil; to adopt in any state where such quarantine is necessary the standardized regulations relating to the phony peach and peach mosaic diseases; and to make further study of the quarantine situation with respect to certain other pests. Attention was brought to the need of discontinuing the dual certification of nursery stock, substituting therefor serially numbered certificates from the states of origin.

Field Status of European Corn Borer Parasites at the Close of 1936

W. A. Baker and W. G. Bradley, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The first releases of imported parasites of the European corn borer, *Pyrausta nubilalis* (Hbn.), were made in the vicinity of Boston, Mass., in 1920, from material of European origin. These were followed by releases in the lake states area beginning in 1924. Since the work was started, a practically continuous series of releases has been made over the entire infested territory, and since 1928 the European material has been supplemented by parasites from the Orient.

Collecting the Data.—Field observations to determine the progress of this work have been conducted concurrently with the field releases of the various species, and this has been an essential feature of the research investigations on the European corn borer by the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture.

The accumulated data on the status of the parasites pertain principally to percentages of parasitization observed at the points of release. Such data were obtained by a section-random sampling technique, consisting of field collections of borers taken at random from uniform sections of the region under observation, supplemented by subsequent laboratory rearing of the collected borers to provide the parasite data. In addition to collecting data on the parasitization, considerable attention has been given to a study of the correlation of fluctuations of host populations with the presence or absence of parasites. At present, however, no practicable technique has been developed that will permit definite interpretations of the influence of parasites on European corn borer populations on the basis of host-population counts.

Tables 1 and 2 relate to parasitization in the overwintering borers of the lake states and eastern states areas at the localities included in the 1936 fall survey program.

At the 14 selected test points, a total of 21 species of foreign parasites have been released since the beginning of colonization activities in 1920. Of this number, five species were recovered in 1936. Details regarding the status of each of these are presented in this paper.

Table 1.—Summary of European corn borer parasites recovered at test points in the lake states area in the fall of 1936.

Locality (Township)	Borers Observed	Foreign Parasites				Native Parasites				Total	
		Lydella stabulans var. *grisescens* R.D.		*Inareolata punctoria* Roman		*Zenillia caesar* Ald.		Undetermined Parasites			
	Number	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Michigan											
Fairfield, Lenawee Co.	592	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Erie, Monroe Co.	670	63	9.40	4	0.60	2	0.30	3	0.45	72	10.75
Ohio											
Jerusalem, Lucas Co.	5007	352	7.03	0	0.00	8	0.16	23	0.46	383	7.65
Perkins, Erie Co.	555	5	0.90	0	0.00	0	0.00	0	0.00	5	0.90
Damascus, Henry Co.	685	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00

Lydella stabulans var. *grisescens* R.D.—This tachinid, which was introduced both from Europe and from the Orient, appeared at three of the five test points examined in the lake states area and at all the points examined at which it had been released in the eastern area.

At Jerusalem Township, Lucas County, Ohio, where *Lydella* has maintained itself for a period of seven years, the percentage of borers parasitized, within individual fields, was unusually high. The percentages of parasitization in the five highest fields were 68.37, 64.36, 62.50, 52.63 and 26.80, respectively. All recoveries were in close proximity to the shore of Lake Erie and associated with a marsh environment. Natural dispersion at this locality is proceeding along the lake front at an

Table 2.—Summary of parasites recovered in the eastern states area in the fall of 1936.

Locality (Township)	Borers Observed	Foreign Parasites												Native* and Undetermined Parasites		Total Parasites	
		Inareolata punctoria Roman		*Lydella stabulans* var. *grisescens* R.D.		*Chelonus annulipes* Wesm.		*Cremastus flavo-orbitalis* Cam.		*Macro-centrus gifuensis* Ashm.		Total					
	Number	Number	Per Cent	Number	Per Cent	Number	Per Cent	Number	Per Cent	Number	Per Cent	Number	Per Cent	Number	Per Cent	Number	Per Cent
Massachusetts																	
Bridgewater, Plymouth Co.	1448	0	0.00	39	2.69	0	0.00	0	0.00	14	0.97	53	3.66	4	0.27	57	3.93
Dighton, Bristol Co.	1508	109	7.23	120	7.96	66	4.37	2	0.13	31	2.05	328	21.75	2	0.13	330	21.88
Malden, Middlesex Co.	2875	355	12.35	74	2.57	0	0.00	0	0.00	0	0.00	429	14.92	4	0.14	433	15.06
Connecticut																	
E. Hartford, Hartford Co.	665	12	1.80	3	0.45	0	0.00	0	0.00	+	—	15	2.25	0	0.00	15	2.25
New Jersey																	
Atlantic, Monmouth Co.	1342	3	0.22	4	0.30	+	—	0	0.00	+	—	7	0.52	1	0.07	8	0.59
Berkeley, Ocean Co.	355	+	—	+	—	+	—	0	0.00	+	—	0	0.00	0			0.00
Maryland																	
Newark, Worcester Co.	74	+	—	2	2.70	+	—	+	—	+	—	2	2.70	—	—	2	2.70
Virginia																	
Franktown, Northampton Co.	377	0	0.00	1	0.26	+	—	1	0.26	+	—	2	0.52	—	—	2	0.52
Lee, Accomac Co.	705	0	0.00	6	0.85	0	0.00	1	0.14	+	—	7	0.99	1	0.14	8	1.13

* Includes the following native parasites: *Labroryckus prismaticus* Nort., *Bassus agilis* (Cress.) and *Zenillia caesar*.
+ No release of this species at this point.

average rate of 1½ miles per year. There has been a continuous increase of parasitization within the area of observation since *Lydella* first became sufficiently numerous to permit parasitization measurements, and an average of 10 per cent was reached in 1936 within a 3½ mile radius of the original point of release. This indicates that equilibrium between host and parasite has not yet been reached. The parasitization at the colony site in Erie Township, Monroe County, Mich., indicates that *Lydella* is well established and maintaining itself in large numbers at that point. At Perkins Township, Erie County, Ohio, however, it appears to have decreased within recent years.

At the older release points in the eastern area, namely Bridgewater, Plymouth County, Dighton, Bristol County, and Malden, Middlesex County, Mass., *Lydella* appeared in practically all collections. Parasitization as high as 19 per cent at Dighton and 13 per cent at Malden was recorded in individual fields. Initial establishment of the species at the point in Newark Township, Worcester County, Md., was indicated by a 2.78 per cent parasitization following a liberation in 1936.

INAREOLATA PUNCTORIA ROMAN.—This ichneumonid has been recovered in small numbers since 1933 at Erie Township, Monroe County, Mich., where releases were made in 1926 and 1928. At two points in the eastern area, Malden and Dighton, Mass., this parasite appeared in samples from all fields except one. At Malden, the oldest release point in the United States, it was the predominating parasite. For the area surveyed at this point, the average parasitization by this species was 12.35 and individual fields showed parasitization as high as 33 per cent. Following a release in 1936, initial establishment of the species was noted at Atlantic Township, Monmouth County, N. J.

CHELONUS ANNULIPES WESM.—In the survey at Dighton, Mass., this species was recovered from seven sections. It accounted for 4.37 per cent of the parasitization in the entire area, and in one section 28.24 per cent of the borers collected were parasitized by this braconid. The presence of this species in numbers at the outer limits of the survey, particularly in one section very near the perimeter, where a parasitization of 14.94 per cent was shown, would indicate that the limits of the distribution of *Chelonus annulipes* at this point are beyond the area that was encompassed in the 1936 survey.

MACROCENTRUS GIFUENSIS ASHM.—This species was recovered for the first time in the United States, unsupported by current releases, at Bridgewater, Mass., in 1934. Its continued maintenance in certain environments was reflected in the 1936 collections by the appearance of 14 parasitizations at Bridgewater and 31 at Dighton, thereby accounting for parasitizations of 1 and 2 per cent, respectively, of the total numbers of borers collected from these two localities. The maximum parasitizations by this species were 20.48 per cent, observed in one collection at Dighton, and 11.83 per cent in one collection from Bridgewater.

CREMASTUS FLAVOORBITALIS CAM.—Two specimens of this species were recovered in 1936 from the Dighton, Mass., collections. This is the first recovery of the species at Dighton, and represents a parasitization of 2.35 per cent of the borers observed in the section from which they were taken. Particular significance is attached to this record because, on the basis of previous observation, it has been considered that the species could not overwinter successfully in the northern states. Initial establishment was accomplished readily at the several points at which this species had been released, but recovery was not effected at these test points in the following season. The current recovery indicates that this species is present in the area on a maintenance basis, but in numbers too small to be recovered generally by means of the sampling technique utilized. *Cremastus* was also recovered from Lee Township, Accomac County, Va., following a release of this species of parasites during the same season.

PARASITIZATION AT MALDEN, MASS.—This locality has supplied the most nearly complete information concerning the relationship of host and parasites of any of the localities where parasites have been released. In the 154 square mile area centering at Malden, and including all of the points of earlier parasite releases, there was a gradual increase of parasitiza-

tion in the overwintering borers from 2.79 per cent in 1927 to 15.16 per cent in 1932, table 3. This percentage has been effected almost entirely by two species, *Inareolata punctoria* and *Lydella stabulans* var. *grisescens*, the amount due to each species having shifted, however, from a predominance of *Lydella* in the earlier years to a predominance of *Inareolata* since 1931. Subsequent to 1931 the parasitization has fluctuated but very little around the 15 per cent level, indicating that this percentage may be considered as representing the equilibrium level in the Malden area. In this same area parasitization of the summer, or first generation, borers has averaged approximately 30 per cent since 1928.

Table 3.—Annual fall parasitization of the European corn borer in the Malden, Mass., area from 1927 to 1936.

Year	Parasitization Per Cent	Year	Parasitization Per Cent
1927	2.79	1932	15.16
1928	5.17	1933	—
1929	6.87	1934	14.53
1930	9.67	1935	16.11
1931	9.87	1936	14.05

NATIVE PARASITES.—Parasitization of the corn borer by native parasites has continued at a very low level generally over the infested area during the entire period of field observations. The species encountered most frequently has been the tachnid *Zenillia caesar*, and parasitization as high as 28 per cent by this species was observed in occasional collections. The total combined parasitization resulting from all native species, however, has never been more than a fraction of 1 per cent.—1-7-38.

Status of the European Corn Borer in 1937[1]

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The European corn borer, *Pyrausta nubilalis* (Hbn.), is now known to be distributed in the eastern counties of Wisconsin and in that portion of the northeastern states composed of all or parts of Indiana, Michigan, Ohio, Pennsylvania, New York and New England and extending down the Atlantic Coast to include New Jersey, southern Delaware, the eastern shore of Maryland and Virginia and several counties on the Virginia mainland.

While intensive scouting to determine the exact limits of the area infested by the corn borer has not been performed by the Bureau of Entomology and Plant Quarantine in recent years, information accumulated in cooperation with various states shows only a slow spread since 1932. In 1934, first records of infestation were received from Hamilton County, Ohio, in the lake states area, and from the following counties in the eastern states area: Cumberland in New Jersey, Sussex in Delaware, Somerset in Maryland and Northampton in Virginia. In 1935, Brown and Calumet Counties in Wisconsin, Boone County in Indiana and Salem County in New Jersey were recorded for the first time as being infested by the corn borer. In 1936, initial infestation was recorded from Norfolk, Princess Anne and Elizabeth City Counties, Va., and Johnson County, Ind.; and in 1937, Winnebago County, Wis., was added to the area known to be infested by the borer. Also in 1937, from scouting records provided by G. T. French, State Entomologist of Virginia, light infestations have been observed in the counties of York, Gloucester, Mathews and Northumberland in Virginia.

ABUNDANCE IN CORN.—Comparative data on the abundance of the European corn borer in corn during 1937 in different infested sections were procured in a survey conducted from August 16 to October 1. Slightly more than one-third as extensive as in 1936, the 1937 survey involved the examination of 880 cornfields, taken at random on a county or county-group basis, within 6 counties in Michigan, 17 in Ohio, 10 in Indiana, 7 in New York, 6 in Massachusetts, 2 in Connecticut, 5 in New Jersey, 1 in Delaware, 2 in Maryland and 2 in Virginia—a total of 58 counties.

[1] Extensive cooperation with the several infested states was maintained in the accumulation of the field status data.

Table 1.—Abundance of the European corn borer in corn in the fall of 1937 as compared with 1934, 1935 and 1936.

County or County Group	Average Number of Borers per 100 Plants			
	1934	1935	1936	1937
LAKE STATES				
Michigan				
Lenawee	13.3	56.4	53.6	147.9
Macomb	20.9	45.9	43.2	178.6
Monroe	27.6	42.9	98.0	215.9
St. Clair	11.8	57.3	69.4	157.7
Washtenaw	2.7	19.5	45.4	75.4
Wayne	7.7	7.2	98.6	131.0
District average	*14.0*	*38.2*	*68.0*	*151.1*
Ohio				
Defiance	8.1	4.8	11.0	27.5
Fulton	30.1	41.0	63.9	67.1
Hancock	25.9	38.8	96.6	66.8
Henry	10.4	44.7	74.2	66.4
Lucas	22.7	121.5	161.5	149.4
Ottawa	22.5	25.9	86.9	99.9
Paulding	3.0	42.1	10.6	31.4
Putnam	3.1	37.6	52.1	45.7
Sandusky	3.8	48.6	107.1	89.3
Seneca	16.7	27.9	31.8	101.8
Williams	2.5	9.2	15.4	33.1
Wood	47.6	91.2	138.4	96.4
Champaign-Darke-Logan-Miami-Shelby	5.0	12.9	0.6	18.8
District average	*15.5*	*42.0*	*65.4*	*68.7*
Indiana				
Adams-Blackford-Jay-Wells	0.3	2.3	0.1	4.4
Allen-DeKalb-Steuben	7.7	27.8	10.9	8.5
Huntington-Noble-Whitley	2.6	5.9	1.6	3.1
District average	*3.5*	*12.0*	*4.2*	*5.3*
New York				
Jefferson-Oswego	41.4	44.8	34.7	21.2
Albany-Fulton-Montgomery-Schenectady-Schoharie	25.4	48.1	—	45.9
District average	*33.4*	*46.4*	—	*33.5*
EASTERN STATES				
Massachusetts				
Essex	105.8	200.5	180.2	225.2
Middlesex	185.9	303.9	155.8	394.0
Franklin-Hampden-Hampshire-Worcester	40.1	20.5	216.9	72.5
District average	*110.6*	*175.0*	*184.3*	*230.6*
Connecticut				
Hartford	61.3	721.4	538.9	1077.2
New Haven	325.0	469.2	391.7	845.5
District average	*193.2*	*595.3*	*465.3*	*961.4*
New Jersey				
Monmouth	20.4	43.4	93.7	157.4
Atlantic-Burlington-Ocean	3.4	33.3	19.4	69.0
Middlesex	—	—	6.7	38.1
District average				
(based on first county and county group)	*11.9*	*38.4*	*56.6*	*113.2*
(based on entire region)	—	—	*39.9*	*88.2*
Delaware				
Sussex	—	—	1.1	5.9
Maryland				
Wicomico-Worcester	—	9.4	0.0	11.4
Virginia				
Accomac-Northampton	—	18.1	5.1	73.1

The Conservation Department of the State of Indiana cooperated actively by surveying the three county groups (120 fields) in Indiana. Assistance was given by the Virginia Truck Experiment Station in determining that infestation by the European corn borer remained extremely light in the counties of Norfolk, Princess Anne and Elizabeth City, on the Virginia mainland.

Thoroughly tested field methods, known to supply data adequate for comparisons between counties and county groups for one or more years, were employed. Generally, the counties situated in the older infested portion of the area were considered separately and in each a total of 20 fields taken at random was surveyed. In the more lightly infested sections the counties were combined in groups of from two to five and in each group a total of 30 or 40 fields taken at random was surveyed. The percentage of plant infestation was determined by a count of 100 plants in each field, and the average number of borers per infested plant was found by a dissection of 10 infested plants in each field of a county unit and of 5 infested plants in each field of a county group.

Table 2.—Summary of European corn borer abundance in corn by states and areas, 1934–37.

Area and State	Number of Counties or County Groups	Average Number of Borers per 100 Plants*			
		1934	1935	1936	1937
LAKE STATES					
Michigan	6	14.0	38.2	68.0	151.1
Ohio	13	15.5	42.0	65.4	68.7
Indiana	3	3.5	12.0	4.2	5.3
New York	1	41.4	44.8	34.7	21.2
Total or average	*23*	*14.7*	*37.2*	*56.8*	*79.9*
EASTERN STATES					
Massachusetts	3	110.6	175.0	184.3	230.6
Connecticut	2	193.2	595.3	465.3	961.4
New Jersey	2	11.9	38.4	56.6	113.2
Delaware†	1	—	—	1.1	5.9
Maryland	1	—	9.4	0.0	11.4
Virginia	1	—	18.1	5.1	73.1
Total or average	*9*	—	*202.2*	*178.0*	*325.0*

* All averages based only on comparable counties or county groups.
† Excluded from areal average.

Information on the abundance of the European corn borer in corn during 1937, in comparison with that of recent years,[2] is summarized in tables 1 to 3, figs. 1 and 2 and in the following discussion.

[2] Records from the Insect Pest Survey Bulletin, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, Vol. 15, No. 9, Supplement, 1935, and Vol. 16, No. 9, Supplement, 1936.

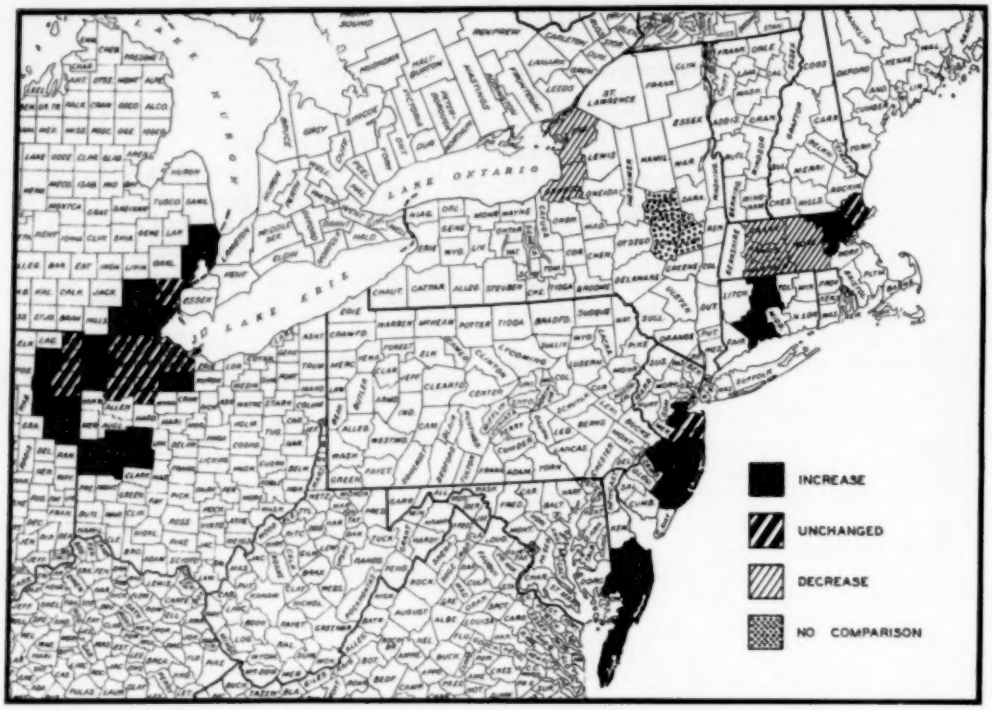

FIG. 1.—Status of the European corn borer in 1937 as compared with 1936.

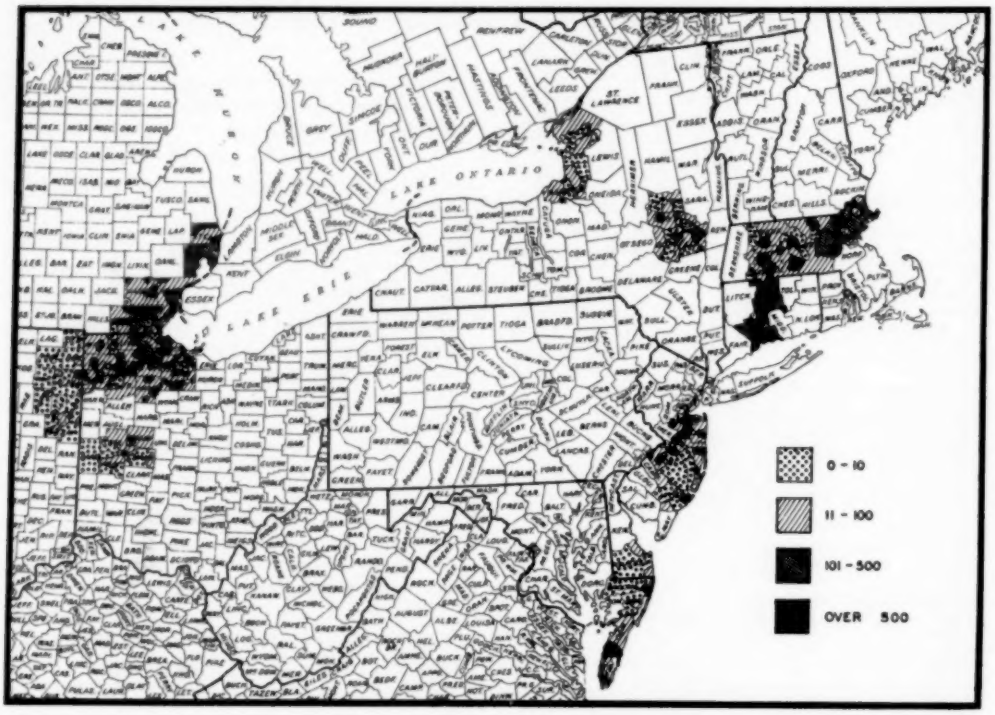

FIG. 2.—Relative abundance of the European corn borer in 1937 as indicated by the number of borers per 100 plants.

LAKE STATES (*Michigan, Indiana, Ohio, and New York*).—In the surveyed portions of Michigan, Indiana and Ohio, taken as a whole, the European corn borer was as generally distributed and as abundant in 1937 as in any previous year of record. Within the territory surveyed in these states in 1937, comprising 18 counties and 4 county groups, there were 9 counties and 3 county groups in which corn borer populations increased significantly from 1936 to 1937, and 9 counties and 1 county group in which the abundance of the insect changed slightly in the same two years. Significant decreases were absent.

Table 3.—Grouping of cornfields surveyed in 1936 and 1937, in comparable counties, according to their borer populations.*

Average Number of Borers per 100 Plants	Per Cent of Surveyed Fields with Indicated Population			
	Lake States		Eastern States	
	1936	1937	1936	1937
0	18.0	9.4	34.8	14.8
1–25	42.0	40.2	22.4	29.3
26–50	11.6	12.7	6.6	8.6
51–100	12.9	15.3	8.6	11.4
101–200	10.4	13.4	10.3	11.4
201–300	3.1	5.3	3.4	5.5
301–400	0.9	1.5	4.1	3.4
401–500	0.7	1.3	1.4	2.7
501–600	0.0	0.5	2.4	3.1
601–700	0.2	0.2	1.4	0.4
701–800	0.2	0.2	1.0	1.7
801–900			0.4	0.7
901–1000			0.4	0.4
1001–2000			2.8	5.2
2001–3000				1.0
3001–3200				0.4

* The percentages for the lake states are based on 550 fields and those for the eastern states on 290 fields, surveyed in each of the two years.

A definite increase in corn borer abundance in 1937 over 1936 was shown along the southeastern edge of Michigan, where the average of 151 borers per 100 plants in 1937 exceeded the average of 68 per 100 plants in 1936. Five of the six counties surveyed in Michigan showed a significant increase in borers from 1936 to 1937 and one had a tendency toward increase. The highest population was recorded in Monroe County and the greatest percentage of increase in Macomb County. All of the 120 fields surveyed in Michigan in 1937 were infested.

Two of the county groups surveyed in Indiana showed increases in infestation in 1937 over 1936, while in the third county group the infestation remained practically unchanged during these two years. The region, as a whole, had about the same low population level in 1937 as in 1936.

In the surveyed portion of northwestern Ohio the status of the corn borer in 1937 remained about the same as in 1936. A significant increase in population of the insect in 1937 over 1936 was found in four counties and one county group in Ohio, with no appreciable change in the remaining eight counties. The most pronounced increase of the borer in Ohio occurred in the Champaign-Darke-Logan-Miami-Shelby county group, the southernmost section surveyed in 1937, where the average number of borers per 100 plants rose from 0.6 in 1936 to 18.8 in 1937, with a more generally distributed infestation in the latter than in the former year.

Although the fall survey, detailed in this discussion, showed that the status of the corn borer remained unchanged in eight of the Ohio counties lying directly to the southwest of the western end of Lake Erie, a considerable number of cornfields, particularly in Lucas and Ottawa Counties, carried high borer populations. Damage to early sweet corn grown near Toledo, Ohio, in 1937 reached economic importance, with an average of 794 borers per 100 plants, according to a survey of 25 of the earliest fields, conducted August 5–13, representing a significant increase from an average of 469 borers per 100 plants found in a similar survey in that section in 1936. Comparable populations in early market sweet corn in this section in 1934 and 1935 averaged 268 and 328 borers per 100 plants, respectively.

In general, the prevailing weather of the 1937 season in the surveyed parts of Michigan, Ohio and Indiana was considered more favorable to the European corn borer than that of any recent year. A wet spring delayed the planting of corn in many fields, however, and it is probable that the consequent lateness of part of the crop, complemented in some cases by decreased vigor of plant growth in wet soils, contributed to a lowered survival of the borer in such fields, whereas a more favorable environment for the insect in the earlier and sturdier corn was conducive to high borer concentrations. Apparently the late planting of much of the

corn in 1937, together with other unfavorable factors, such as severe rain and wind storms in some sections at crucial periods of larval establishment, offset the effects of a season otherwise favorable to increased abundance of the corn borer.

In New York there occurred during 1937 a decrease in corn borer abundance as compared with 1936 in the Jefferson-Oswego county group, while approximately the same numbers of borers were present in the Albany district in 1937 as were found during the last survey, made in 1935.

EASTERN STATES (*Massachusetts, Connecticut, New Jersey, Delaware, Maryland, and Virginia*).—Along the Atlantic Coast, the European corn borer increased in abundance in 1937 over 1936 in a portion of eastern Massachusetts, in central Connecticut, in southeastern New Jersey, in southern Delaware and on the eastern shore of Maryland and Virginia. The only exception to an increase or tendency in that direction was in western Massachusetts, where a significant decrease in borer population in 1937 was shown by the survey.

In Middlesex County, Mass., there occurred an increase from an average of 155.8 borers per 100 plants in 1936 to 394 in 1937, while in Essex County, Mass., no significant change in borer population took place between the same two years. In the county group of Franklin-Hampden-Hampshire-Worcester, in western Massachusetts, the average population of 216.9 borers per 100 plants in 1936 declined to 72.5 in 1937.

The heaviest borer populations found in 1937, or in any other year of survey in the United States, occurred in Hartford and New Haven Counties, Conn. In the former county the average of 538.9 borers per 100 plants in 1936 doubled itself to 1077.2 per 100 plants in 1937, and in the latter county the average of 391.7 borers per 100 plants in 1936 doubled itself to 845.5 per 100 plants in 1937. Half of the 20 cornfields surveyed in Hartford County in 1937 averaged more than 1000 borers per 100 plants, and 7 out of the 20 fields surveyed in New Haven County had populations of this size. For the combined counties, the proportion of fields with more than 1000 borers per 100 plants increased from 17.5 per cent in 1936 to 42.5 per cent in 1937. The maximum number of 3200 borers per 100 plants was found in one field in Hartford County.

In New Jersey the survey showed significant increases in corn borer abundance in 1937 over 1936 in Middlesex County and in the Atlantic-Burlington-Ocean county group, with a strong tendency toward significant increase in Monmouth County. In the last county the average number of borers per 100 plants reached 157.4, and half of the fields surveyed in it had over 100 borers per 100 plants, with two fields out of 20, or 10 per cent, exceeding 500 borers per 100 plants.

Corn borer abundance in Sussex County, Del., increased from an average of 1.1 borers per 100 plants in 1936 to an average of 5.9 in 1937, with infestation noted in 37 per cent of the fields surveyed in 1937 as compared with 10 per cent in 1936. The maximum population in a single field in Delaware in 1937 was 56.6 borers per 100 plants.

In the Wicomico-Worcester county group in Maryland, where no borers were found during the 1936 survey, there was an average of 11.4 borers per 100 plants in 1937, 40 per cent of the fields examined being infested. The maximum number of borers in a single field in Maryland was 135.5 per 100 plants.

Increased infestation by the European corn borer also appeared in the Accomac-Northampton county group in Virginia, where the average number of borers per 100 plants rose from 5.1 in 1936 to 73.1 in 1937, with the insect present in the latter year in all 40 fields surveyed. Over 100 borers per 100 plants were recorded for 12.5 per cent of the fields, with maximums of 424 and 372.6 borers per 100 plants in two of them.

A conclusive explanation of the general increases in corn borer abundance along the Atlantic Coast in 1937 is not offered at this time. It may be assumed with a considerable degree of certainty, however, that favorable weather conditions at propitious periods of the insect's development in the field were the influencing factors, with emphasis on the absence of drought in 1937. In Connecticut the increased corn borer infestation in 1937 over 1936 was due principally to an extremely heavy deposition of second-generation eggs, indicative of moisture and temperature conditions in the field favorable to the moths during oviposition. Deposi-

tion of first-generation eggs and larval establishment in both generations, near New Haven, Conn., were practically the same in 1937 as in 1936.

ABUNDANCE IN POTATOES.—Supplementing the general fall survey of corn borer populations in corn, a survey of infestation by the first generation in potatoes was conducted during the last two weeks of July, 1937, on eastern Long Island, N. Y., in central Connecticut and in west-central Massachusetts. A large part of the last two districts lies in the Connecticut River Valley. In each of the three districts, 25 fields of potatoes, taken at random, were examined according to tested survey methods. The data obtained from these districts are summarized in table 4.

Table 4.—Summary of data on corn borer infestation in potatoes, Long Island, N. Y., Connecticut, and Massachusetts, 1937.

DISTRICT	PERIOD OF SURVEY	NUMBER OF FIELDS	AVERAGE PER CENT OF PLANTS INFESTED	AVERAGE NUMBER OF BORERS PER 100 PLANTS	PER CENT OF FIELDS INFESTED BY BORER	PER CENT OF FIELDS WITH AVERAGE OF OVER 100 BORERS PER 100 PLANTS
Eastern Long Island, N.Y.	July 17–21	25	30.3	60.0	88.0	24.0
Central Connecticut	July 22–27	25	48.4	106.2	88.0	44.0
West-Central Massachusetts	July 27–31	25	23.5	73.5	56.0	20.0

Similar surveys of the infestation in potatoes had been conducted on eastern Long Island from 1932 to 1935, inclusive, and the average numbers of borers per 100 plants for those years, respectively, were determined as 22.8, 64.0, 48.7 and 30.1. In 1937 the average number of borers per 100 plants in the same region was 60.

Potatoes in central Connecticut and west-central Massachusetts had not been surveyed previously for corn borer infestation. In the former district the average number of borers per 100 plants in 1937 was 106.2, and in the latter, 73.5. Although the two fields with the highest borer populations (580 and 400 per 100 plants) were found in Massachusetts, there were practically twice as many fields with an average of over 100 borers per 100 plants in Connecticut as in either the Long Island or the Massachusetts district. Both on Long Island and in Connecticut 88 per cent of the fields showed infestation by the corn borer as compared with 56 per cent of the fields in Massachusetts. The maximum number of borers found in a single potato plant in 1937 was 12.—1-7-38.

The Literature of American Economic Entomology

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The literature of American economic entomology has been written almost entirely within the past century. Thaddeus William Harris was the pioneer. He wrote nearly a hundred popular articles on the more troublesome or injurious insects of his time. These articles appeared for the most part in agricultural or local papers. His work was summarized in that classic known as "Insects Injurious to Vegetation." He appreciated the importance of the strikingly practical written in a style easily understood by the men of his time. He impressed upon his public the desirability of a comprehensive volume, a publication which was issued in a number of editions. He established the fundamentals of economic entomology in this country. It should be noted that much of this was accomplished by the printed word.

PIONEER LITERATURE.—The same general methods were characteristic of the associates and followers of Harris, notably Fitch of New York, Walsh and Le Baron of Illinois, and Riley of Missouri and Washington, and they were char-

acteristic of at least the earlier days of Riley's highly gifted associate and successor, Dr. L. O. Howard, a man who has had a far reaching and practically illimitable influence upon the development of economic entomology throughout the world.

The significant point in the work of these earlier entomologists is the strikingly practical nature of their writings. They were planned for the enlightenment of an agricultural population more concerned with immediate results than with scientific theories in relation to the origin and development of insect life.

The American literature of economic entomology is much more than a voluminous record of interesting facts concerning a large number of native and introduced insects. It is the story of a remarkable development made possible by the fact that the pioneers built wisely and well. This is more readily appreciated after reading one or more of the four histories of entomology which have appeared in recent years.

The literature of the early days was restricted largely to popular articles in the current press and to more or less voluminous annual reports, the subject matter of these latter being determined mostly by the developments of each season. With the beginning of this century there was a gradual change to detailed publications, mostly bulletins, on individual insects or related groups of insects with an occasional general summation comparable to Harris' "Insects Injurious to Vegetation." A few years ago there was a tendency to minimize the importance of the popular article. That attitude has been largely corrected in the development of extension entomology and the preparation of innumerable articles for both practical and casual readers. Occasionally one of the more striking phases of entomology is presented by a popular writer in a medium having a large national circulation. Such accounts must be based on accurate information which can be obtained only through research. They appeal to the public because of the human interest and this latter calls for a sense or perception rarely found in the investigator.

LATER PUBLICATIONS.—Numerous bulletins issued by state and federal agencies have made available to the public comprehensive and in some instances most detailed accounts of different insect pests. Exhaustive studies of important groups have been published, such as the well known work, "Mosquitoes of North America" by Howard, Dyar and Knab with its exquisitely accurate illustrations. The latter part of the century of entomology has witnessed the publication of a number of excellent school and college texts as well as general works dealing with agricultural or other insects. There are also the entomological serials unknown in the days of Harris, the JOURNAL OF ECONOMIC ENTOMOLOGY being the leader in its particular field. The bibliographies of American economic entomology of earlier years and the more recent issues of the *Index* afford ready and essential guides to the multitudinous details recorded in our literature.

SPECIALIZATION IN RECENT LITERATURE.—The extent and diversity of recent economic entomological literature is rarely appreciated. That in relation to the codling moth graphically illustrates the difference between earlier entomological activities and those of the present day. The earlier articles were concerned largely with injury and relatively simple and direct methods of control.

A comprehensive summation of our knowledge of the codling moth was written by the late Mark Vernon Slingerland. It appeared in 1898 as Bulletin 142 of the Cornell Agricultural Experiment Station. It was considered at that time as the last word in regard to the pest and presumably brought information respecting the insect to a satisfactory and more or less final summation. Five years later this pest was discussed in an extended bulletin with an exhaustive bibliography issued by the Federal Government and in the transmittal written by a leading entomologist is this statement: "The present publication is the final and complete report, elaborating all of the conclusions and results of this special investigation." There is at least an implication in these words that the subject was well and possibly conclusively discussed.

The subsequent literary history of the codling moth leads to a totally different conclusion. The records of later years indicate numerous publications, some extensive, on this pest. There was from 1930 to 1934 an average of nearly 200 articles

annually. Furthermore, there have been annual conferences on this insect for a number of years, one being held in connection with this series of meetings. At the present time, more entomologists are studying the codling moth and the problems in relation thereto than at any earlier period in the history of this insect. The diversity of the problem is indicated by the subheadings in the *Index* for the above mentioned five year period, namely: "Apple Plug," "Attrahents," "Banding," "Breeding Cages," "Cost of Control," "Drop Disposal," "Egg Laying," "Emergence Records," "Experiments," "Flights," "Hibernation," "Instinct," and so on down the alphabet to "Traps" of various types. Harris advised destroying infested fruit and banding. He was not troubled with arsenical residues.

The entries in the *Index* for the period of 1930 to 1934 in relation to insecticides further illustrate the complexities confronting the present day entomologist. Some 200 general references are followed by others classified under subheads such as "Acid Phosphate," "Advertising," "Aliphatic Thiocyanates," "Anabasine," "Analysis," "Antidotes," "Aphicides," "Argentine Ant Poison," "Arsenates," "Arsenic," "Arsenicals," with subheadings on "Substitutes" and "Toxicity," "Arsenious Oxides," and through a considerable series of other listings to "Zinc Sulphide." Specialization in the study of injurious insects and methods of control is evidently walking hand in hand with specialization in the study of insecticides and their possibilities. The entomologist of today needs to be something of a chemist or at least be where he may profit by the guidance of an authority on the chemistry of insecticides.

The field of the economic entomologist has broadened greatly in the last fifty years and at the present includes insects which may injure man either by annoying him or by inoculating him with serious or deadly infections. The extent of this phase of entomology is indicated by some 100 different references in the above mentioned *Index* to "Malaria" during a five year period, while the general subject of "Mosquitoes," their "Control" and the "Diseases They Disseminate" requires nearly 600 additional citations. Furthermore, there is an extensive and constantly increasing literature on the insects affecting domestic animals. There is also a considerable literature developing in relation to the insects affecting forest and shade trees. None of these was given more than passing consideration in the earlier days.

Biological control is another phase of entomology which has been given much attention in the last forty years or thereabouts in connection with the extensive depredations of a number of introduced pests. The work on natural enemies of the gypsy moth, the Japanese beetle and the European corn borer has been concerned primarily with the introduction and establishment of parasites, and, in the case of the oriental fruit moth in particular, several states are propagating and disseminating parasites. The European corn borer has provoked exhaustive studies of the possibilities of mechanical control, really an intensive form of clean culture, as well as a study of parasites. The above are only a few illustrations of the present day specialization in the field of economic entomology.

TYPES OF PUBLICATIONS.—The form of publication and nature of the contents are of great importance, since they determine in considerable measure the appeal to the average man and consequently its value, since an unread publication is a total loss. It is obvious that the average individual is not particularly interested in the extensive and general entomological records of earlier years. These are primarily of interest to entomologists, and their place is being taken to some extent at least by federal and state bulletins. THE JOURNAL OF ECONOMIC ENTOMOLOGY and to a lesser extent *The Annals of the Entomological Society of America* disseminate much technical information to entomologists. The extremely valuable technical, and sometimes extended, bulletins dealing with insect biology and control, particularly biological control, also should be limited in their distribution to professional workers.

There has been during recent years increasing attention to brief, popular notices in regard to insects and their control. This is practically the type of information which was the foundation of the work of the earlier entomologists. There is a call for the same type of information now except that it must be brought down to date and presented in a form which ap-

peals to the man of today. Such literature appears now, as in former years, in current publications, that relating to farm pests being largely in the agricultural press. Both federal and state agencies appreciate the importance of popular or semipopular publications such as circulars or leaflets, extension bulletins, extension circulars, information cards, and even mimeographed or manifold leaflets. These publications are more or less ephemeral in nature.

There is a decided advantage in distributing printed information, since verbal statements or hurried notes are frequently unreliable. The radio message is an excellent supplement. It is possible that facsimile transcription of brief messages, a process now in its early stages, may become as easily available as the radio message and prove a major aid to extension entomology.

Attractiveness in both language and appearance adds greatly to the value of economic literature. One of the most satisfactory publications from this aspect is the series of leaflets entitled "Common Insect Pests of New York State"; nos. 1 to 13 have appeared to date. These are comprehensive, non-technical, four page circulars, each dealing with one of the more important insects and carrying on the first page a colored illustration of the insect in its various stages and its work, thus giving the reader at a glance a definite idea of the story presented in the leaflet. Another recent and noteworthy publication in this respect is that just issued by the Nassau County Extermination Commission entitled "Mosquitoes, Their Life History and Control." It consists of a series of well illustrated accounts dealing with the various phases of mosquito control in a suburban area.

Economic entomology has need for all types of literature. Its value depends largely upon the accuracy of the record and the method of presentation. The latter is determined in large measure by the needs of those to whom it is directed. The aim is to meet a definite need.

The literature of American economic entomology is much more than a long series of records concerning insects and their activities. It is in addition a history of the development of this phase of science and as such is worthy of careful study. It represents in large measure the ambitions of hundreds who have devoted their lives to a study of insects in the hopes of rendering material aid to their fellow men. The best evidence of their success is found in the more general appreciation of the possibilities of economic entomology as evidenced by marked changes in the methods of agriculture, horticulture and medicine and by a corresponding expansion of personnel and resources for both research and instruction.—1-7-38.

Codling Moth Oviposition and Temperature[1]

DWIGHT ISELY,[2] *University of Arkansas, Fayetteville*

Timing of spraying operations for control of codling moth, *Carpocapsa pomonella* L., usually is regarded as dependent upon a knowledge of the time eggs are deposited. For this reason moths are reared in large numbers, or the time of their occurrence is determined by bait-trap collections. However, the abundance of moths is not in itself an altogether dependable indication of an ensuing abundance of eggs, since if unfavorable climatic conditions occur there will be little or no reproduction. Hitherto, most attention has been directed toward the beginning of emergence of moths of the spring brood and of the summer broods, and the peak of emergence of the spring brood. It has been assumed that, after oviposition has once started, it will continue until the end of the season. In most seasons, however, there are periods of at least a few days which are unfavorable to it. General tendencies are readily observed in the field, but short deviations may escape notice without cage records.

This paper deals chiefly with the effect of mean daily temperatures upon oviposition of the codling moth. Most of the

[1] Research Paper No. 489, Journal Series, University of Arkansas.

[2] The writer was assisted in the rearing work by E. L. Gilliland and W. D. Wylie in 1936, and by J. O. Dockins and Garvin Green in 1937.

records relate to oviposition by moths of the summer broods in 1936 and 1937. To add to the temperature scale and for comparison, oviposition records for the overwintered brood of 1937 are included. The work reported was carried on in the apple area of northwestern Arkansas at Fayetteville.

EXPERIMENTAL PROCEDURE.—Each female used in these records was isolated in a battery jar cage on the day of emergence. As a rule, to increase the chance for fertilization, two males were placed with each female. The moths were fed very dilute honey from 2-dram homeopathic vials through a small piece of sponge, which served as a wick, stuffed into the mouth of the vial. This kept the sponge moist at all times. A circular piece of blue paper was fitted in the bottom of each cage, which, because of contrasting color, facilitated the counting of eggs deposited there. After oviposition began, the moths were transferred to new cages each morning and the eggs were counted. No apple foliage was placed in the cages nor was any other attempt made to simulate natural conditions, since previous trial had shown no advantage in doing so. About two-thirds of the females in these cages deposited eggs when temperatures were favorable. Moths which failed to oviposit where discarded and were not included in the averages.

DAILY OVIPOSITION.—Individual variation in oviposition among moths was very great. This may have been due to differences in evening temperatures, to extremely high temperatures for a few hours, to unfavorable conditions during the larval life of the insects, or to other conditions. These possible sources of error are recognized, but in this paper only the effect of mean temperature is considered.

An increase in temperature tends to increase the daily oviposition of the codling moth under the climatic conditions which usually prevail in northwestern Arkansas. In a way, this is readily supported by field observations, for usually the years of relatively high temperatures have been the years of heavy infestation. While oviposition may be expected to decline when the optimum temperature is passed, during most seasons the daily mean temperature seldom rises above the optimum for enough days in succession to produce results that would attract attention in the field. For instance, the daily mean temperature for July, the hottest month of the year at Fayetteville, based on 50 years of records, is 25.78 degrees C. (78.4 degrees F.).

The most favorable mean daily temperature for oviposition, according to cage records, during 1936 and 1937 was 27 degrees C. (80.6 degrees F.). As the daily mean rose above this point or fell below it, the average number of eggs deposited by each moth declined gradually until the temperatures became excessively high or low, after which the decline was rapid. The average number of eggs deposited on days when the mean temperature was 27 degrees C. was 19.22. Frequently individual daily records were over 100 eggs to one moth. When the temperature rises above optimum, the rate of oviposition of some moths actually may be increased, although the lives of those moths is shortened. A summary of the records of daily oviposition at temperatures of from 18 degrees to 33 degrees C. is shown in table 1.

Table 1.—*Carpocapsa pomonella*.—Daily oviposition at mean temperatures ranging from 21 degrees to 33 degrees C., Fayetteville, Ark., 1936 and 1937.

MEAN DAILY TEMPERATURE IN DEGREES C.	NUMBER OF FEMALE MOTHS	AVERAGE NUMBER OF EGGS DEPOSITED
21	104	8.45
22	128	6.74
23	240	10.66
24	303	13.84
25	301	16.09
26	522	17.12
27	259	19.22
28	279	17.39
29	189	14.41
30	117	16.40
31	114	14.54
32	67	11.27
33	12	7.00

Excessively high temperatures repress reproduction. The reduction in codling moth infestation was evident in orchards in 1934 and again in 1936, when a heavy "worm" population in mid-July faded rapidly with the advance of the season and was almost negligible in late August. This was easily observed by the decline in infestation of the fruit. It was shown later by decline in number of worms collected in bands, and was followed in about two weeks by a similar decline in

numbers of moths collected in bait-traps.

The repressive effect of high temperatures is not so evident, however, in averages of oviposition shown in table 1, as it was in the field, because a few moths in the cages deposited large numbers of eggs at high temperatures. The most important effect of high temperature was in stopping the oviposition of most moths altogether, and not in the gradual reduction of the number of eggs from those moths that continued to deposit them. For example, the highest number of eggs deposited by a single moth on one day was 142, when the mean temperature was 30 degrees C. However, this was the only moth among those under observation to deposit eggs that day. The failure of moths to deposit eggs does not appear in the average daily oviposition, shown in this table.

Heat waves for even a few days tend to prevent newly emerged moths from ever depositing eggs. During a period of 30 days between June 23 and July 22, 1937, the temperatures were very favorable to the codling moth on all but two days. However, on those two days, July 4 and 5, a short heat wave occurred. Of the moths that emerged during the entire 30 days, 142 females were isolated in cages with males. Approximately two-thirds of them (65.42 per cent) deposited eggs. Of the moths that emerged during the two-day heat wave, only 18.18 per cent deposited eggs. The excessive temperature apparently had an inhibiting effect on the fecundity of the moths which transformed on the succeeding day. If moths from these three days are excluded from the averages, those which deposited eggs exceeded 71 per cent.

DURATION OF OVIPOSITION PERIOD.—Possibly the most important effect of excessively high temperatures was that eggs deposited by moths which, as larvae and pupae, had been exposed to excessive temperatures tended to be sterile.

Temperatures too low to be favorable to high daily oviposition reduced the daily activity of the moths, which resulted in lengthening the reproductive period. During the cool weather which prevailed during much of the life of adults of the overwintered brood, egg laying was intermittent and often was interrupted for periods of days. The effect of low temperature was to reduce the daily rate of oviposition, although this was offset in part by prolonging the oviposition period. It also affected the regularity of oviposition as is shown by the low percentage of females that had completed their preoviposition period and which deposited eggs on days when low temperatures prevailed. In the field this delay of oviposition is probably injurious to the species, because it increases the chance of moths being killed before their period of reproduction is completed.

Near the end of the season when there was intermittent cool weather during which little oviposition occurred, the number of eggs deposited on warm days was proportionately higher than the number deposited when the temperature was continuously high enough for regular oviposition.

The number of eggs deposited by moths of the summer broods was higher at the same temperatures than the number of eggs deposited by moths of the spring brood. Furthermore, moths of the summer brood which matured early in July deposited more eggs on the average than moths maturing later, when the daily temperatures were the same. There appeared to be a tendency for the number of eggs deposited at a given temperature to decline until near the end of the season.

The temperature most favorable to daily oviposition is not the temperature favorable to the greatest total oviposition. Increasing temperature does not necessarily increase the total number of eggs deposited during the entire life of a moth. This temperature accelerates the reproductive activity of the moth while it lives, but this activity shortens its life. According to records of 439 moths, the oviposition period was longest when the mean temperature for the entire period was 23 degrees C., and tended to decline as the mean temperature rose or fell. As the temperature rose about 28 degrees C., the mean period shortened rapidly, and at 32 degrees C., or above, it averaged less than two days. A summary of these records is shown in table 2.

TOTAL OVIPOSITION.—The largest total number of eggs was deposited by moths when the mean temperature for the entire oviposition period was 25 degrees C. According to records for both seasons,

based on complete oviposition records, an average of 146 eggs was deposited when the mean temperature for the entire oviposition period was 25 degrees C. During 1937 the average for 57 moths at 25 degrees C. was 157.90 eggs. The highest total record of eggs deposited by a single moth was 345. These data are summarized in table 3. They show the adaptability of the codling moth and its ability to reproduce under a wide range of temperature conditions.

Table 2.—*Carpocapsa pomonella*.—Duration of oviposition period at mean temperatures ranging from 21 degrees to 33 degrees C., Fayetteville, Ark., 1936 and 1937.

MEAN DAILY TEMPERATURE IN DEGREES C.	NUMBER OF FEMALE MOTHS	MEAN OVIPOSITION PERIOD IN DAYS
21	11	11.27
22	24	12.00
23	14	13.36
24	41	7.66
25	64	8.48
26	39	7.95
27	56	7.43
28	72	8.43
29	35	5.51
30	39	5.10
31	32	4.94
32	6	1.50
33	6	1.33

The mean oviposition period of moths of the summer brood in 1937 was approximately a week, but occasionally it was much longer and in a single instance extended to 20 days. Over one-fifth of the eggs (21.16 per cent) was deposited on the first day of oviposition and the numbers tended to decline as the period became more extended. Over 90 per cent of the eggs was deposited during the first seven days.

The oviposition period of the overwintered brood, which was on the wing in May and June when the temperatures were lower, was proportionately longer. Slightly less than one-sixth of the eggs (15.95 per cent) was deposited the first day and 12 days passed before 90 per cent of the eggs was deposited.

The preoviposition period of 51 moths of the overwintered brood in 1937 averaged 5.47 days. For the 192 moths of the summer broods of the same year the average was 3.18 days.

Table 3.—*Carpocapsa pomonella*.—Total oviposition of moths at mean temperatures for entire period ranging from 21 degrees to 33 degrees C., Fayetteville, Ark., 1936 and 1937.

TEMPERATURE IN DEGREES C.	TOTAL NUMBER OF FEMALE MOTHS	TOTAL NUMBER OF OF EGGS	AVERAGE OVIPOSITION FOR TOTAL PERIOD
21	11	1199	109.00
22	24	2078	86.58
23	20	1969	98.45
24	46	5607	121.89
25	67	9782	146.00
26	42	5304	126.29
27	60	6958	115.97
28	73	8406	115.15
29	37	2678	72.38
30	39	1963	50.59
31	32	1958	61.19
32	6	137	22.83
33	6	72	7.00

SUMMARY.—An increase in temperature, under usual climatic conditions in northwestern Arkansas, tends to increase the daily oviposition of the codling moth. The optimum temperature for oviposition appears to be 27 degrees C. Excessively high temperatures tend to reduce the average number of eggs deposited by moths which continue ovipositing, and abruptly terminates the oviposition period of others. It may also produce sterility of the eggs deposited. The effect of short periods of excessive temperature may not be noticed in the field. Low temperatures retard daily oviposition but prolong the oviposition period of the moths. Low temperatures also cause irregular daily oviposition. The largest total number of eggs was deposited by moths when the mean temperature of the oviposition period was 25 degrees C. During midsummer, over 90 per cent of the eggs is deposited during the first seven days of the oviposition period; in spring the same per cent of oviposition requires 12 days. This information may not be useful in planning a summer spraying schedule but should be useful in interpreting results in experimental work.—1-7-38.

THE STATES of Utah and Washington have recently placed standardized quarantines relating to the peach mosaic disease.

EXPERIMENT stations of Illinois, Indiana and Kentucky, and the Illinois Natural History Survey sponsor weekly radio bulletins on insect movements.

The Kind of Radiation Most Attractive to the Codling Moth: A Progress Report

G. Edward Marshall and T. E. Hienton,[1] *Agricultural Experiment Station, Purdue University, Lafayette, Ind.*

Studies made in 1931 and 1932 disclosed that blue was one of the most attractive colors to the codling moth. Subsequent investigations were carried on to find the kind of radiation most attractive to the codling moth. In 1933, notable results were obtained in catches made by the use of a dozen light traps,[2] and it was during the fall of that year that the largest catches of codling moths were made. In that year more than 200 moths were taken in one night from one trap. During the same night, light traps in eight trees made a catch of more than 500 moths. At harvest the same year and in the same orchard, the apple crop was a failure. However, a study of the cost of operating the lamps and traps was sufficiently interesting to warrant further and more detailed investigations in this field.

Cost of Killing Codling Moth With Lights.—The true value of the measure could have been ascertained only if light traps had been used over the entire planting and the losses of fruit chargeable to the codling moth had been added to the installation and operation costs. It is probable that in years when the infestation is light, and consequently the traps catch fewer moths, the losses of fruit would be less and fewer dollars worth of apples would have to be charged to the inefficiency of light traps. Under such conditions light traps would pay bigger dividends than was the case in 1933. In years of light infestations the cost of killing 100 moths by electrocution would be many times greater than in heavy population years such as 1933. Even then it is probable that light traps would more nearly pay their own way.

The cost of producing a bushel of apples should be considered in a study of this kind. It was determined (Troth & Marshall 1935) during an eight-year period that this cost is 77.5 cents per bushel in the older orchards and in areas where the codling moth may produce a partial third brood. These figures apply fairly well to the southern half of the apple producing belt of the entire Central West. That portion of the total per bushel cost, chargeable to the codling moth alone, is 33.47 cents, or 43.04 per cent of the total cost of producing a bushel of apples.

Such figures warrant the exhaustive study of any control practice of greater economy or efficiency that offers promise. To find a dependable, effective, nonspray control for this insect would be to eliminate a major hazard in apple production. Thus, if the moth population in an orchard could be reduced through the use of light traps to insure (a) a commercially clean crop (not more than 15 per cent injured by the codling moth); (b) the elimination of washing the fruit and much of the grading expense; (c) the increase of the tree vigor that would result in annual bearing instead of a crop every other year; then much of the losses in orcharding could be averted, the outlook would be brighter and many growers who face business failure might continue in production.

Extent of Control by Light Traps.—By the use of 1000-hour, 100-watt *Mazda C* lamps in light traps in a 4.5 acre orchard area, the reduction of the codling moth attack was found to be about 50 per cent after a two-year test had been conducted by the United States Department of Agriculture. Parrott & Collins (1935) of New York found that light traps were about as effective as two sprays under New York conditions.

It is considered that commercial control of the codling moth is not attained if more than 15 per cent of the fruit is affected by this insect. It would seem, therefore, that there remains the problem of increasing the effectiveness of light traps by finding a more attractive lure, inasmuch as the best position in the tree for traps, the best time to operate them

[1] The writers wish to express their gratitude to L. C. Porter and J. P. Ditchman of the General Electric Company, Nela Park, Cleveland, Ohio, for furnishing a great deal of special equipment used in these tests.

[2] Where the term light trap is used in this paper, it refers to an electrocutor type trap with an electric lamp which is used as the attrahent.

and the periods of heaviest flights have been determined.

Light traps placed in a packing house during the time moths emerge has long since demonstrated the economy of this method of preventing the insect from returning to the orchard to lay its eggs. This is especially true if the building is screened. During the studies which determined this point, 15,579 moths emerged and were destroyed in one day by placing a light trap on each floor of a two story packing house. With the exercise of moderate care in darkening the building so that a lamp would attract during the day as well as at night, all except 1.32 per cent of the moths that emerged were attracted and destroyed.

The annual destruction of all the moths from the packing houses alone would have prevented many growers in past years from being forced out of business. It has been suggested to apple producers that one or more light traps in the orchard around the packing house, or other farm buildings where apples have been stored, is an excellent means by which the daily flight activities of this insect may be determined as an aid in the timing of sprays, thinning the fruit and timing other orchard operations which are determined by moth flight.

THE 1937 FIELD WORK.—The results of investigations made prior to 1937 have been published elsewhere (Marshall & Hienton 1935a; Marshall & Hienton 1935b). During the past season both field and laboratory studies were conducted. In the field work, four different intensities of light were used in a triplicated set-up and a similar study was conducted in the laboratory. Table 1 summarizes the results and shows that an increase in efficiency was obtained by increasing the light intensity. This work was outlined after it had been learned that *Photoflood* lamps were very attractive to the moths. Such lamps are short lived and expensive and for this reason an attempt was made to reduce the lamp cost and yet approach its lumen output. The regular 1000-hour, 100-watt *Mazda C* inside-frosted lamps were used with others in which the life of the lamp was shortened to 25, 100 and 500 hours respectively. This reduction in life changed the spectral distributions to those shown in tables 3 and 4. It will be noted that the amount of radiation in the blue and violet was greater for the shorter lived lamps.

Table 1.—Field catch of codling moths with 100-watt Mazda C lamps.

CATCH	25-HOUR LAMP	100-HOUR LAMP	500-HOUR LAMP	1000-HOUR LAMP
Total catch	685	509	392	466
Per trap per day	3.10	2.30	1.77	2.11

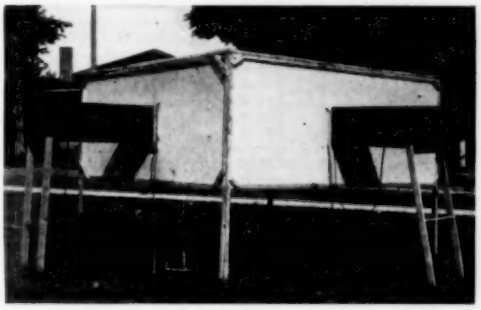

FIG. 1.—Outside view of lure chamber used in studying the attractiveness of different types of radiation to codling moth.

These figures in the tables emphasize the evidence already obtained that intrinsic brilliance and color from blue and violet to shorter wave lengths are very attractive. The tests with the General Electric *H-3* lamp enclosed in an *A-21 Corex D* glass bulb also demonstrate this point. The *H-3* is a high pressure 85-watt mercury arc lamp which radiates 10 times as much ultraviolet as the *G-5* lamp. When the catches for the 1000-hour lamp are compared with those from the 25-hour one, it is found that the lamp of short life attracted 33 per cent more moths in the field. From the table of radient intensities, it will be seen that as the life of the lamp is shortened more radiation is created in the violet and blue region of the spectrum and also in the near ultraviolet.

THE 1937 LABORATORY WORK.—In the laboratory, a lure chamber 10 by 10 by 4 feet was constructed for the tests and was painted mat black on the inside, fig. 1. In the center of each side was an opening 6 inches square through which was admitted the radiation to be tested. Below each 6 inch opening in the wall, a slide

Table 2.—Comparisons of the attractiveness of some lamps to the codling moth.

Test No.	Filter Used	Box No.	Foot-Candles Used	Moths Used	Lamps Used and Moths Killed by Each							
					Box 1	Moths Trapped	Box 2	Moths Trapped	Box 3	Moths Trapped	Box 4	Moths Trapped
1	*Corex D*	1 2 3 4	172.5 277.0 206.7 248.0	137	*G-5*	123	250-W. *CX*	0	No. 3 *Photoflood*	7	100-W. C	7
2	*Corex D* Lead glass	1 2	430.0 430.0	41	*G-5*	28	*G-5*	13				
3	Lead glass *Corex D*	1 2	330.0 330.0	54	250-W. *CX*	26	250-W. *CX*	28				
4	Lead glass *Corex D*	1 2 3 4	330.0 330.0 330.0 330.0	57	*G-5*	17	*G-5*	8	*H-3*	7	*H-3 Spec.*	25
5	*Corex D*	1 2 3 4	1280.0 160.0 320.0 640.0	71	250-W. *CX*	49	250-W. *CX*	5	250-W. *CX*	9	250-W. *CX*	8
6	*Corex D* Lead glass	1 2	1280.0 1280.0	40	250-W. *CX*	18	250-W. *CX*	22				
9	*Corex D*	1	200.0	119					*H-3*	38	*H-3 Spec.*	56
10	*Corex D* Lead glass	3 4	300.0 300.0	62					250-W. *CX*	26	250-W. *CX*	29
14	*Corex D*	1 2 3 4	150.0 150.0 150.0 150.0	166	1000-hr. 100-W.	24	100-hr. 100-W.	42	25-hr. 100-W.	68	500-hr. 100-W.	14
15	*Corex D*	all	150.0	78	500-hr. 100-W.	10	25-hr. 100-W.	23	1000-hr. 100-W.	12	100-hr. 100-W.	11
16	*Corex D*	all	150.0	102	100-hr. 100-W.	29	1000-hr. 100-W.	14	500-hr. 100-W.	15	25-hr. 100-W.	44
17	*Corex D*	all	150.0	84	25-hr. 100-W.	34	500-hr. 100-W.	6	100-hr. 100-W.	30	1000-hr. 100-W.	4
18	*Corex D*	1 2 3 4	1.1 2.0 1.0 1.4	93	25-hr. 100-W.	1	Robin's egg blue 100-W.	0	Dark blue 200-W.	91	1000-hr. 100-W.	1
19	*Corex D*	1 2 3 4	1.1 2.0 1.0 1.4	106	25-hr. 100-W.	0	Robin's egg blue 100-W.	1	Dark blue 200-W.	105	1000-hr. 100-W.	0
20	*Corex D*	1 2 3 4	160 1280 640 320	98	250-W. *CX*	1	250-W. *CX*	71	250-W. *CX*	20	250-W. *CX*	2
21	*Corex D*	1 2 3 4	640 320 1280 160	129	250-W. *CX*	33	250-W. *CX*	2	250-W. *CX*	50	250-W. *CX*	1
22	*Corex D*	1 2 3 4	320 640 160 1280	123	250-W. *CX*	9	250-W. *CX*	12	250-W. *CX*	2	250-W. *CX*	88
23	*Corex D*	all	320	137	250-W. *CX*	43	250-W. *CX*	12	250-W. *CX*	51	250-W. *CX*	7
24	*Corex D*	all	320	101	250-W. *CX*	43	250-W. *CX*	3	250-W. *CX*	8	250-W. *CX*	45
25	*Corex D*	all	320	73	250-W. *CX*	3	250-W. *CX*	37	250-W. *CX*	3	250-W. *CX*	23
26	*Corex D*	all	320	175	250-W. *CX*	4	250-W *CX*	42	250-W. *CX*	38	250-W. *CX*	7
27	Lead glass *Corex D*	1 2	150 150	88	*G-5*	53	*G-5*	29				
28	Lead glass *Corex D*	1 2	150 150	120	*G-5*	75	*G-5*	29				
29	*Corex D* Lead glass	1 2	150 150	102	*G-5*	56	*G-5*	29				
30	*Corex D* Lead glass	1 2	300 300	97	*H-3 Spec.*	51	*H-3 Spec.*	28				

Table 2 (Continued)

Test No.	Filter Used	Box No.	Foot-Candles Used	Moths Used	Lamps Used and Moths Killed by Each							
					Box 1	Moths Trapped	Box 2	Moths Trapped	Box 3	Moths Trapped	Box 4	Moths Trapped
31	Lead glass *Corex D*	1 2	300 300	48	*H-3 Spec.*	16	*H-3 Spec.*	26				
32	*Corex D*	all	2	78	*H-3 Spec.*	13	*G-5*	14	Dark blue 200-W.	37	Fluorescent tube	3
33	*Corex D*	all	2	56	*G-5*	19	*H-3 Spec.*	7	Fluorescent tube	0	Dark blue 200-W.	22
34	*Corex D*	all	2	66	*G-5*	17	*H-3 Spec.*	10	Fluorescent tube	2	Dark blue 200-W.	33
35	Lead glass *Corex D*	3 4	250 250	78					*H-3 Spec.*	25	*H-3 Spec.*	50
36	*Corex D* Lead glass	3 4	250 250	49					*H-3 Spec.*	26	*H-3 Spec.*	18

door was cut in the floor; by opening these doors, the dead moths could be counted. The slide doors were opened after the moths had been attracted to the radiant sources and had flown against charged wires placed in front of the openings emitting the light. A current of constant voltage with controlled identical and measured lamp output in foot-candles was used in these tests. Also employed were newly emerged moths, a pre-determined spectra distribution of the lamps used and lights from which certain spectral bands were eliminated. During each test, the voltage was maintained at exactly 115 by means of a rheostat.

Several different filters were used; the lead glass screened out all the ultra-violet and the *Corex D* permitted the ultra-violet to be radiated into the lure chamber. Also used were red, red purple, ultra and purple *Corex A* filters. The lamps used had glass bulbs which in some cases restricted or emitted certain wave bands. An illuminometer was employed to measure the foot-candle output from each lamp. The radiant energy was admitted into the lure chamber through a diffusion plate and the amount of radiation admitted could be controlled in two ways: (a) by increasing or decreasing the distance of the lamp from the plate; (b) by reducing or increasing the opening in the iris diaphragm set between the lamp and the plate, fig. 2. By these methods the same number of foot-candles from each lamp tested could be thrown on the plate, or the size of the luminous area could be varied as much as desired.

The codling moths used were obtained by picking wormy apples from the trees early in the summer and placing the apples in a screened enclosure, in which the moths emerged. All the newly emerged moths were collected each day by the use of a modified vacuum cleaner.

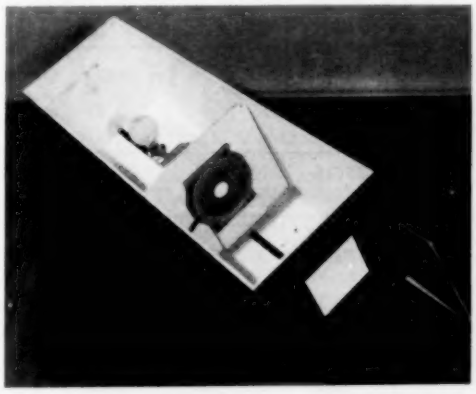

FIG. 2.—Equipment used to control amount of light admitted to lure chamber.

RESULTS OF LABORATORY WORK.—In table 2 are recorded the results of some of the tests that were run in the laboratory. By means of test 1 and others which were similar, it was hoped that a rather definite idea as to the color value or approximate wave length of radiant energy most attractive to the moth could be obtained. It may be seen that although the radiation was least intense on the plate in which there was a *G-5* lamp, box 1, test 1, by far the greatest number of moths was attracted to it. By referring to table 3, it will be seen that the *G-5* lamp is much richer than most of the others in near, middle and far ultra-violet and also in part of the violet range of the spectrum.

Table 3.—Radiant intensities of some lamps used in tests,* microwatts per cm² at 1 meter distance.

FIELD	WAVE LENGTH (A)	250-W. *CX*	*H-3 Special*	100-W. 750-Hr.	100-W. 500-Hr.	100-W. 100-Hr.	100-W. 25-Hr.	*G-5*
Far ultra-violet	2483		0.12					
	2537		0.07					0.004
	2576							
	2652	0.0002	0.83					0.02
	2699	0.0009	0.58					
Middle ultra-violet	2753	0.002	0.68					
	2804	0.0045	1.19					0.02
	2894	0.0115	1.51					0.17
	2925	0.015	1.02					0.02
	2967	0.020	4.3					0.42
	3022	0.028	5.1					0.26
Near ultra-violet	3129	0.051	13.2					2.4
	3341		3.2					0.24
	3500	0.16		0.030	0.033	0.052	0.071	
	3650– 3663		25.7					3.2
Violet and blue	4000	0.48		0.098	0.106	0.151	0.178	
	4047		14.5					5.4
	4358		27.1					7.0
	4475– 4550		2.6					0.0
	4500	1.04		0.238	0.254	0.340	0.42	
	3650– 4840		2.2					0.0
	4840– 5060		2.05					0.0
Green	5000	1.76		0.435	0.480	0.581	0.68	
	5060– 5320		2.2					0.0
	5320– 5615		33.5					6.2
	5500	2.52		0.66	0.62	0.83	0.96	
Yellow	5615– 5950		19.2					2.3
	5950– 6350		3.1					
Orange and red	6000	3.58		0.89	0.93	1.07	1.19	
	6350– 6830		3.0					
	6500	4.44		1.12	1.15	1.30	1.41	
	6830– 7220		3.75					
	7000	5.07		1.31	1.34	1.47	1.57	
Infra-red	7500	5.55		1.47	1.50	1.61	1.68	
	8000	5.95		1.60	1.62	1.70	1.76	
	8500	6.25		1.70	1.71	1.77	1.81	
	9000	6.42		1.75	1.76	1.79	1.81	
	9500	6.50		1.80	1.79	1.81	1.80	
	10000	6.52		1.81	1.80	1.79	1.77	
	10140		10.8					3.2
	10500	6.52		1.82	1.81	1.77	1.74	
	11000	6.44		1.78	1.77	1.71	1.67	
	11289		7.8					
	11900–12100		6.3					
	12000	6.12		1.69	1.67	1.60	1.53	
	13000	5.45		1.57	1.55	1.45	1.29	
	13570–13955		8.5					
	14000	4.85		1.43	1.41	1.31	1.22	
	15000	4.33		1.28	1.26	1.14	1.07	
	15300		6.1					
	16000	3.62		1.14	1.11	1.01	0.94	
	16900–17100		6.9					
	17000	3.15		1.00	0.97	0.87	0.81	
	18000	2.74		0.87	0.85	0.76	0.69	
	19000	2.39		0.76	0.74	0.65	0.60	
	20000	2.09		0.66	0.64	0.56	0.51	
	22000	1.63		0.52	0.50	0.43	0.40	
	24000	1.26		0.39	0.38	0.32	0.30	
	26000	1.04		0.31	0.30	0.26	0.23	

* These data furnished by General Electric Lamp Works, Cleveland, Ohio.

The percentages of total light of various kinds is shown in table 4.

Other tests which contribute data on this same question of radiant energy are five: 18, 19, 32, 33 and 34.

In test 4, a lead glass filter was used in box 1. Such a filter transmits no ultra-violet; therefore, it would seem that the blue and violet radiated by this lamp

Table 4.—Per cent of total light in lamps used.*

	VIOLET AND BLUE	GREEN	YELLOW	ORANGE AND RED
100-W. 1000-hr.	2.3	40.7	27.4	29.6
100-W. 500-hr.	2.6	41.6	26.6	28.2
100-W. 100-hr.	2.9	43.1	26.5	27.5
100-W. 25-hr.	3.0	43.8	26.5	26.7
250-W. *CX*	2.7	42.5	26.8	28.0
G-5	1.6	73.6	24.8	0.0
H-3	1.6	64.2	31.3	2.9

* These data furnished by General Electric Lamp Works, Cleveland, Ohio.

was the attractive principal. The *Corex D* diffusion plates transmit ultra-violet; all the other boxes were equipped with these. Although the *G-5* attracted the largest number of moths in the tests mentioned previously, it will be seen that this was true only if the *Special H-3* was not run in competition with it. When the *H-3* was used, although the *G-5* attracted several moths, the *H-3* always attracted a larger number. When the dark blue 200-watt was used in competition with the *G-5* and the *Special H-3*, with the intensities the same, the dark blue lamp always led in attractiveness. Here again, it would seem that blue color is very attractive to the moths since the 200-watt dark blue radiates very little ultra-violet.

TESTS OF INTRINSIC BRILLIANCE AND SIZE OF LUMINOUS AREA.—The methods used and results obtained in an attempt to determine the effects of intrinsic brilliance and size of luminous area are briefly described.

1.—250-watt *CX* lamps were placed at such a distance from the ground glass diffusion plates that the foot-candle intensities on these plates approximated a ratio of 1–2–4–8. For the results of this test see table 2, tests 5, 20, 21 and 22. In test 5, the intensities were determined at Cleveland, Ohio, by L. C. Porter and J. P. Ditchman of the General Electric Company before the lamp boxes were shipped to Orleans. In the other three tests the intensities were checked just prior to liberation of the moths. The following summary of the four tests indicates the differences in response to various light intensities:

Foot-candles	1280	640	320	160
Total catch	298	73	24	9

2.—The lamps were all placed the same distance from the diffusion plates and iris diaphragms were used to regulate the sizes of luminous area so that they would be in a ratio of 1–2–4–8 on the plates (tests 23, 24, 25 and 26).

The total catches in the four tests demonstrate the effect of the size of the luminous body on the number of moths attracted.

Ratio luminous areas	8	4	2	1
Diameter luminous area	4.24 in.	3.0 in.	2.12 in.	1.5 in.
Total catch	163	169	100	17

TESTS OF ATTRACTIVENESS OF ULTRA-VIOLET RADIATION.—In attempting to determine whether ultra-violet radiation is an important factor in the attractiveness of lamps, five tests, 2, 4, 27, 28 and 29, were made. In these tests, *G-5* lamps were compared, with and without filters which removed the ultra-violet rays. In this instance the most attractive by 20 per cent was that without ultra-violet. In like comparisons, tests 3, 6, 9 and 10, in which 250-watt *CX* lamps were used, the radiation with the ultra-violet was just as attractive as were those with the ultra-violet screened out. In fact, in these four different tests, the total catch of all was the same for the radiation with ultra-violet as it was in those in which this band was eliminated. These results indicate that the blue and violet is just as attractive alone as when a small amount of ultra-violet is included in the energy radiated.

When the *Special H-3* lamps were used, with and without the ultra-violet screened out, tests 30, 31, 35 and 36, the difference was much greater in favor of the ultra-violet. In these four tests the most at-

tractive lamp by 44 per cent was the *H-3* operated to permit the ultra-violet to be radiated into the lure chamber. These tests indicate that if there is a relatively large amount of ultra-violet radiation, then it becomes important in attractiveness along with the visible violet and blue.

A test similar to the 1937 field test was made to determine whether or not a change in brilliancy, with such change in the color spectrum as results from operating lamps over-voltage, would indicate a definite trend toward higher attractiveness. For this test, all four boxes were equipped with 100-watt special *Mazda* lamps designed to have 25-, 100-, 500- and 1000-hour lives, respectively. Tests 14, 15, 16 and 17 of table 2 give the results of this voltage increase. The total number of moths attracted in all four tests is as follows:

25-hour	100-hour	500-hour	1000-hour
169	112	45	54

CONCLUSIONS.—As a result of the foregoing tests, the authors feel there are three things which influence the attractiveness of light to the codling moth; namely, intrinsic brilliance, the size of the luminous area and the color. Small amounts of ultra-violet, in addition to blue and violet, seem to have little attraction. Large amounts of ultra-violet, based comparatively on the lamps used in the tests, add to the attractiveness of the lamp. It would seem that the best lamp to attract the codling moth would be one with the right shade of blue, with great intrinsic brilliance and with a large luminous area. The dark blue 200-watt tungsten filament lamp, when all other conditions were equal, showed the greatest attractiveness of all lamps tested.

Consideration of the results herein recorded should recall that these data were obtained under the condition of this experiment and with the equipment available at the time. Other laboratory tests may or may not parallel these results in every respect.—5-13-38.

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Experiments With Tank-Mix Nicotine-Bentonite-Soybean Oil for Codling Moth Control

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The object of this report is to present the results of three years of field and laboratory-field tests, carried on in southern Indiana, of a tank-mix nicotine-bentonite-soybean oil combination for codling moth control. During the past five years, combinations of nicotine and bentonite have been tested by various investigators, generally with promising results. Some of the earliest work was done by Driggers & Pepper (1934), mostly with nicotine sulfate or nicotine tannate in combination with bentonite or bentonite-sulfur, but without oil.

Among the various combinations of nicotine with bentonite that have been under experiment at the Vincennes, Ind., station since 1933 the most effective in codling moth control has consisted of nicotine sulfate (40 per cent nicotine), 1 pint; bentonite, 5 pounds; soybean oil, 1 quart; and sodium lauryl sulfate, one-fourth to one-half ounce per 100 gallons. Chemical analyses of spray deposits made by J. E. Fahey and H. W. Rusk of the Division of Insecticide Investigations have shown also that, for the purpose of building up and maintaining highly toxic

deposits of nicotine over long intervals, the tank-mix soybean oil treatment was one of the most effective tested.

LABORATORY-FIELD TESTS.—The method of laboratory-field tests originally described by Lathrop & Sazama (1932) was utilized each season but with some modifications and improvements. Small plots were sprayed in the usual manner with a standard portable spray outfit, under 450 pounds of pressure through two three-nozzle "brooms," one of which was used from a tower 10 feet high. An average of 20 to 25 gallons per tree was required for each application.

Fruit sampled from the plots was taken into the laboratory, where it was arranged in a well replicated set-up and exposed to attack by a known number of larvae. Efficiency was calculated by comparisons of the kill obtained on the treated fruit with that on washed or unsprayed fruit. Stings were recorded but did not enter into the larvicidal efficiency rating. Thus the influence of all factors other than the spray deposit on the surface of the fruit is eliminated. This method does not measure the effect of foliage deposits nor of the calyx spray, the ovicidal effect of a treatment nor the end results at harvest. It probably underestimates the mortality that would be obtained under field conditions, but it gives an approximation of the kill to be expected of larvae that hatch on the surface of the fruit under the most favorable conditions. Observations indicate that, when by this method larvicidal efficiencies exceed 85 per cent, the treatment is giving almost perfect control in the field if the population and weather conditions are normal.

In 1935 the samples consisted of 100 apples to which 600 larvae were applied. In 1936 and 1937 they consisted of 80 apples, but 640 larvae were used. Samples were taken from top, middle and bottom sections of two trees in each plot. The first samples were taken a day or two after worms began hatching in the orchard. Subsequently the treatments were sampled before and after each cover spray and on other intervening dates.

The reliability of the sampling technique and experimental design has been thoroughly tested by statistical analysis and appears to be more than adequate. The analysis of variance (Snedecor 1934) was applied to each experiment.

The season of 1935 was unusually cool and rainy, 1936 was extremely hot and dry and 1937 was nearly normal. Thus the nicotine-bentonite treatment was subjected to a wide variety of weather conditions. Seasonal conditions, however, had no influence on larvicidal efficiency as determined in the laboratory, except through their effect on the character or amount of the spray deposits.

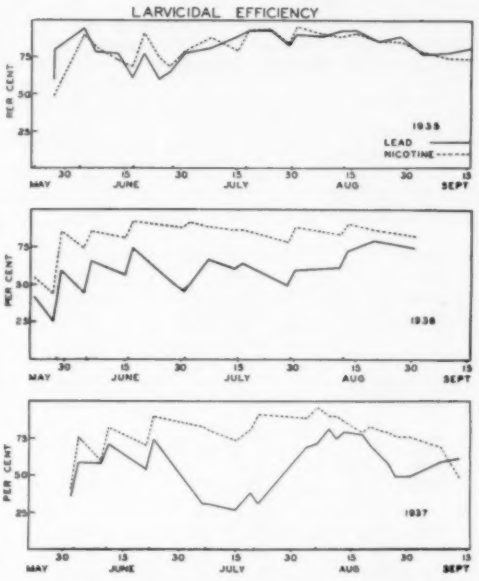

FIG. 1.—Per cent larvicidal efficiency of lead arsenate and tank-mix nicotine-bentonite-soybean oil spray treatments, 1935–1937.

The spray mixtures and treatments, the dates the fruit samples were taken, the rainfall between sampling dates, the larvicidal-efficiency data for each treatment and the difference required to be considered as significant at odds of 99 to 1 are given in tables 1, 2 and 3, and the relative larvicidal efficiencies are shown graphically in fig. 1.

RESULTS OF LABORATORY-FIELD TESTS.—Throughout these tests an effort has been made to compare the nicotine-bentonites with the most effective available lead arsenate program. The efficiencies resulting from the lead arsenate combinations used in 1935 were the highest that have ever been obtained at the Vincennes laboratory, but the materials caused considerable foliage injury and left residues that could not be re-

moved with heated acid solutions. The triethanolamine oleate plus oil plus lead arsenate mixture used in 1936 did not build the deposits expected, probably because of the addition of bordeaux mixture and the hardness of the water used. The lead arsenate program followed in 1937 was that recommended by the Illinois and Indiana Agricultural Experiment Stations in 1937 for the control of severe infestations in those states. This treatment caused considerable foliage injury and left residues very difficult to remove.

Throughout the tests the nicotine-bentonite mixtures were equal to or better than lead arsenate in effectiveness except for early in 1935, when three applications of lead arsenate were compared with one of nicotine-bentonite, and at the very end of the 1937 season, more than a month after the final spray applications. The nicotine-bentonite maintained its effectiveness through periods of heavy rainfall in 1935, and throughout the excessive heat and drought of the summer of 1936.

The results indicated that after a high efficiency is attained and the rate of fruit growth declines, the dosage of nicotine and bentonite may be reduced by 50 per cent and the spray intervals lengthened without any substantial drop in the average effectiveness of the treatment. Chemical analyses showed that heavy deposits were present after most of the applications and that these could weather off to a considerable extent before the efficiency began to decline.

No foliage injury was observed at any time in the nicotine-bentonite plots. In some cases there were conspicuous deposits of bentonite on the fruit at harvest,

Table 1.—Larvicidal efficiency of lead arsenate and nicotine-bentonite on 20-year-old Grimes and amount of rainfall between sample dates, Vincennes, Ind., 1935.

Date	Rainfall in Inches	Larvicidal Efficiency		Difference in Per Cent	Required Difference for Odds of 99:1 in Per Cent
		Lead Arsenate* in per cent	Nicotine† in per cent		
May 27	1.28	80.5	49.7	−30.8	13.2
June 4	1.54	94.7	90.5	− 4.2	8.7
June 7	0.90	79.0	82.7	3.7	13.3
June 13	0.81	77.8	74.0	− 3.8	10.3
June 17	2.04	61.3	69.6	8.3	11.9
June 20	1.20	77.8	91.9	14.1	9.4
June 24	0.24	60.4	75.5	15.1	12.2
June 27	0.38	65.3	69.8	4.5	11.4
July 1	0.60	78.7	79.9	1.2	9.2
July 8	1.43	81.8	88.9	7.1	9.1
July 15	Trace	89.7	80.2	− 9.5	15.1
July 18	0.00	93.4	93.4	0.0	5.9
July 24	0.26	93.3	94.4	1.1	9.3
July 29	0.51	83.8	85.1	1.3	11.6
July 31	0.00	90.7	96.1	5.4	6.6
Aug. 7	2.88	89.5	91.5	2.0	10.9
Aug. 12	0.00	93.1	89.2	− 3.9	12.6
Aug. 16	1.11	93.9	91.3	− 2.6	11.2
Aug. 22	0.06	86.2	86.4	0.2	11.3
Aug. 28	1.20	89.5	85.7	− 3.8	11.2
Sept. 3	0.24	77.7	78.9	1.2	11.0
Sept. 10	0.68	78.7	74.6	− 4.1	11.3
Sept. 16	0.00	81.7	73.7	− 8.0	11.0

* Received following schedule (quantities per 100 gallons): May 17, 21, 27; June 3: Lead arsenate, 4 lbs.; Hydrated lime, 4 lbs.: Sodium oleate soap, ¼ lb.; White oil (tank emulsified), ½ gal.; June 17, 28; July 18, 30; Aug. 13: Lead arsenate, 3 lbs.; Bordeaux mixture, 3–1½–100.

† Sprayed on May 21; June 3, 17, 28; July 18, 30; Aug. 13 with the following (per 100 gallons): Sodium lauryl sulfate, ½oz.; Nicotine sulfate, 1 pt.; Bentonite, 5 lbs.; Soybean oil, 1 qt. These were added to the tank in the order indicated.

but these were readily removed by washing in a brush machine with weak alkali. In some cases dry brushing was sufficient to remove the residue.

The tank-mix nicotine-bentonite-soybean oil treatment must be used in spray outfits that have excellent agitation. Because of the physical nature of the bentonite it must be poured in slowly. With insufficient agitation or improper wetting, brood hatch, may thus be subjected to heavy attack by progeny of larvae which survived the lead arsenate treatment early in the season. Condemnation of such a treatment because of failure to equal lead arsenate in small plot tests may therefore be unjustified.

FIELD TESTS IN 1937.—Field experiments were carried on in 1937 near Elberfeld, Ind., in which nicotine-bentonite

Table 2.—Larvicidal efficiency of lead arsenate and nicotine-bentonite on 21-year-old Jonathan and amount of rainfall between sample dates, Vincennes, Ind., 1936.

DATE	RAINFALL IN INCHES	LARVICIDAL EFFICIENCY		DIFFERENCE IN PER CENT	REQUIRED DIFFERENCE FOR ODDS OF 99:1 IN PER CENT
		Lead Arsenate* in Per Cent	Nicotine† in Per Cent		
May 22	0.00	41.8	54.8	13.0	9.8
May 27	0.00	25.3	43.1	17.8	9.0
May 29	0.00	59.6	85.1	25.5	8.0
June 4	1.24	44.3	74.1	29.8	10.0
June 6	0.00	65.8	85.7	19.9	6.7
June 15	0.14	56.6	81.3	24.7	9.6
June 17	0.00	74.5	92.0	17.5	6.4
June 30	0.34	46.0	88.4	42.4	10.3
July 2	0.19	49.5	91.3	41.8	9.4
July 7	1.01	66.6	88.3	21.7	9.0
July 14	0.52	60.8	86.2	25.4	12.0
July 16	0.09	64.1	86.6	22.5	11.7
July 28	1.66	48.9	78.4	29.5	10.1
July 30	0.00	59.9	88.4	28.5	7.2
Aug. 11	1.73	61.7	83.1	21.4	9.8
Aug. 13	0.00	72.2	90.5	18.3	7.7
Aug. 20	0.10	79.9	86.7	6.8	7.9
Aug. 31	0.09	74.5	82.6	8.1	9.8

* May 11: Lead arsenate, 3 lbs.; Lime, 3 lbs.; May 19, 28, June 5, 16: Lead arsenate, 3 lbs.; Kerosene, 2 qts.; Triethanolamine oleate, 150 cc.; Bordeaux mixture, 3–1½–100. (Trees oversprayed with double gallonage.) July 1, 15, 29, Aug. 12: Lead arsenate, 3 lbs.; Bordeaux, 3–1½–100.

† May 19, 28, June 5, 16: Sodium lauryl sulfate, ½ oz.; Nicotine sulfate, 1 pt.; Bentonite, 5 lb.; Soybean oil, 1 qt.; July 1, 15, 29, Aug. 12: Same as above formula, except nicotine sulfate and bentonite each reduced one-half.

difficulties with clogged screens may develop.

WEAKNESSES OF FIELD SPRAY TESTS IN SMALL PLOTS.—It is the writers' observation that, in a two- or three-brood area, interplot movement of moths exerts such a leveling influence where small replicated spray plots are used that the early season effects of any particular treatment are seldom known when only drop and harvest infestation records are obtained. A treatment that is highly superior to lead arsenate in the first brood, and which happens to be inferior at the time of third

and lead arsenate were each applied to duplicate 2½-acre plots of the Golden Delicious variety. Six nicotine and seven lead arsenate sprays were applied, the final spraying being given on July 30. The fruit was harvested Sept., 28, at which time no visible bentonite deposit remained. Control by each treatment was nearly perfect. Only one worm entrance per 400 apples was found in each area. Sixteen bait traps scattered through the area caught an average of 44 moths each during the season.

Because no fungicide was used with

nicotine-bentonite, except in the first spray, a severe infection of bitter rot developed in the nicotine area. This disease had been common in the orchard in preceding years but it was held in check in 1937 by the $\frac{3}{4}$–$1\frac{1}{2}$–100 Bordeaux used with the last six lead arsenate sprays. The incompatibility of nicotine-bentonite with the usual fungicides is a complicating factor, and diseases which require summer applications may be difficult to control unless some of the newer fungicides prove satisfactory.

Wettable sulfur was used in combination with the first nicotine-bentonite spray. The soybean oil was omitted from that application but included with the others. It was observed in this and other experiments that oil, either mineral or soybean, could follow sulfur at a shorter interval with safety when combined with nicotine-bentonite than when used with lead arsenate.

PRACTICAL GROWER TESTS OF NICOTINE-BENTONITE.—As a result of the 1935 and 1936 laboratory-field tests, the W. C. Reed & Son Orchard Company at Vincennes, Ind., decided to use the tank-mix nicotine-bentonite-soybean oil combination on nearly half its acreage in 1937. This offered an opportunity to observe the behavior of this material when used on a very much larger scale than had previously been possible. Accordingly a nicotine program was suggested for use on 90 acres. The lead arsenate schedule applied to the remaining 122 acres of orchard was arranged by the grower, who

Table 3.—Larvicidal efficiency of lead arsenate and nicotine-bentonite on 22-year-old Jonathan and amount of rainfall between sample dates, Vincennes, Ind., 1937.

DATE	RAINFALL IN INCHES	LARVICIDAL EFFICIENCY		DIFFERENCE IN PER CENT	REQUIRED DIFFERENCE FOR ODDS OF 99:1 IN PER CENT
		Lead Arsenate* in Per Cent	Nicotine† in Per Cent		
June 1	0.23	35.8	41.1	5.3	11.9
June 3	0	58.4	75.2	16.8	9.0
June 9	1.42	58.5	60.5	2.0	6.1
June 11	.36	71.1	82.1	11.0	8.8
June 21	2.04	54.1	70.5	16.4	11.3
June 23	0	74.6	90.0	15.4	6.2
July 6	.67	31.4	83.4	52.0	9.1
July 8	Trace	30.9	80.3	49.4	7.7
July 15	.45	27.1	74.1	47.0	9.1
July 19	.23	38.6	81.4	42.8	10.2
July 21	.01	31.4	91.2	59.8	7.0
Aug. 3	.16	69.6	89.1	19.5	3.8
Aug. 6	.49	72.0	96.3	24.3	5.6
Aug. 9	0	81.7	90.3	8.6	7.0
Aug. 11	.61	75.2	90.2	15.0	7.0
Aug. 13	.04	79.5	86.8	7.3	8.9
Aug. 18	0	77.9	79.5	1.6	11.1
Aug. 20	0	71.1	83.3	12.2	13.7
Aug. 23	1.00	63.3	80.6	17.3	13.7
Aug. 25	0	58.3	79.5	21.2	9.6
Aug. 27	0	48.9	76.4	27.5	10.4
Aug. 31	Trace	48.9	76.2	27.3	11.9
Sept. 8	.92	59.0	69.8	10.8	10.2
Sept. 13	2.78	61.7	48.1	−13.6	8.6

* Received the following treatment: May 13: Lead arsenate, 4 lbs.; Hydrated lime, 4 lbs.; Soybean flour, $\frac{1}{2}$ lb.; May 24: Lead arsenate, 4 lbs.; Bordeaux, $\frac{3}{4}$–$1\frac{1}{2}$–100; Soybean flour, $\frac{1}{2}$ lb.; June 2: Lead arsenate, 4 lbs.; Summer oil, 2 qts.; Bordeaux, $\frac{3}{4}$–$1\frac{1}{2}$–100; June 11: Lead arsenate, 3 lbs.; Summer oil, 2 qts.; Bordeaux, $\frac{3}{4}$–$1\frac{1}{2}$–100; June 22, July 7, 20, Aug. 6: Lead arsenate, 3 lbs.; Bordeaux, $\frac{3}{4}$–$1\frac{1}{2}$–100.

† May 25, June 2, 11, 22: Sodium lauryl sulfate, $\frac{1}{2}$ oz.; Nicotine sulfate, 1 pt.; Bentonite, 5 lbs.; Soybean oil, 1 qt.; July 7, 20, Aug. 6: Same as above formula, except nicotine sulfate and bentonite each reduced one-half.

Table 4.—Spray programs followed in grower experiment with nicotine-bentonite, Vincennes, Ind., 1937.

Application	Lead Arsenate Program			Nicotine Program		
	Dates	Material		Dates	Material	
Calyx	May 5–6	Lead arsenate	2.8 lbs.	May 6–8	Lead arsenate	2.8 lbs.
		Hydrated lime	2.5 lbs.		Hydrated lime	2.5 lbs.
		Spreader	0.2 lb.		Dry lime sulfur	2.0 lbs.
		Sulfur	10.0 lbs.		Dusting sulfur	8.0 lbs.
					Glue	0.1 oz.
First Cover	May 17	Lead arsenate	3.2 lbs.			
		Hydrated lime	1.5 lbs.		No application made	
		Commercial copper fungicide (20% metallic copper and 4% metallic zinc)	6.0 lbs.			
Second Cover	May 19–20	Lead arsenate	3.2 lbs.	May 24	Nicotine sulfate	0.60 qt.
		Hydrated lime	2.5 lbs.		Bentonite	5.00 lbs.
		Dry lime sulfur	2.0 lbs.		Raw soybean oil	0.20 gal.
		Dusting sulfur	8.0 lbs.		Sodium lauryl sulfate	0.25 oz.
Third	May 26–27	Lead arsenate	4.0 lbs.	May 28–29	Nicotine sulfate	0.50 qt.
		Hydrated lime	1.5 lbs.		Bentonite	5.00 lbs.
		Copper sulfate	0.6 lb.		Soybean oil	1.00 qt.
					Sodium lauryl sulfate	0.25 oz.
Fourth Cover	May 31–June 2	Lead arsenate	3.20 lbs.	June 4–5		
		Triethanolamine	0.15 pt.		Same as third cover	
		Oleic acid	0.30 pt.			
		Mineral oil*	0.50 gal.			
Fifth Cover	June 8	Lead arsenate	3.20 lbs.	June 15	Nicotine sulfate	0.5 qt.
		Hydrated lime	1.50 lbs.		Mineral oil	2.0 qts.
		Triethanolamine	0.15 pt.		Commercial copper fungicide (emulsifier)	0.6 lb.
		Oleic acid	0.10 qt.		Triethanolamine	0.1 qt.
		Commercial copper fungicide	0.60 lb.		Oleic acid	0.2 qt.
Sixth	June 29–July 1	Lead arsenate	3.20 lbs.	July 3		
		Hydrated lime	1.50		Same as third cover	
		Copper sulfate	0.75 lb.			
		Mineral oil	1.00 qt.			
Seventh Cover	July 21–24	Same as sixth cover, except mineral oil omitted		July 20–21	Same as third cover	
Eighth Cover	July 29	Lead arsenate	3.2 lbs.	July 29	Nicotine sulfate	0.25 qt.
		Hydrated lime	1.5 lbs.		Bentonite	5.00 lbs.
					Soybean oil	0.20 gal.
					Sodium lauryl sulfate	0.25 oz.
Ninth Cover	–	No application made		Sept. 1	Mineral oil	0.6 gal.†
					Commercial copper fungicide (emulsifier)	0.6 lb.

* The mineral oil used had a viscosity of 74 seconds (Saybolt Universal Viscosimeter at 100 degrees F.). This is a deposit-building formula, and the trees were sprayed with an average of 34 gallons, instead of the usual 18.

† Intended as an aid in masking and weathering off the bentonite residue.

wished to use as intensive a treatment as the trees could tolerate and residue removal requirements would permit.

The orchard was in excellent condition and making vigorous growth. The trees were open and low, facilitating spraying from the ground. Most varieties common to southern Indiana were represented, with Transparent and Duchess trees interplanted among the fall and winter varieties. The entire acreage was sprayed from a central stationary outfit. For this reason and because the grower wished to include the early varieties in the nicotine

program to avoid washing, it was not practical to replicate the treatments in different parts of the orchard.

The nicotine area was bounded on three sides by that part of the orchard sprayed with lead arsenate and on the fourth side by an adjacent orchard which also was sprayed with lead arsenate. It contained most of the trees of the interplanted early varieties and probably on this account it had been supporting the largest codling moth population. The nicotine-sprayed Ben Davis trees were nearest the packing house and prior to this experiment produced the wormiest fruit in the orchard.

nicotine area received an average of 15 gallons per application and those in the lead arsenate area an average of 20 gallons. Ben Davis in the nicotine area averaged 10 gallons and those in the lead arsenate area, 13 gallons. Part of the difference was due to the extra gallonage applied in the fourth cover spray to the lead arsenate area and part to an effort to conserve on the more expensive nicotine solution. In addition, the marked color contrast between wet and dry foliage sprayed with nicotine-bentonite makes it easier to avoid overspraying.

Eight Transparent, seven Turley and

Table 5.—Codling moth control in nicotine and lead arsenate areas, Vincennes, Ind., 1937.

Area	Variety	Number Per Tree			Number Per 100 Apples	
		Apples	Worms	Stings	Worms	Stings
Nicotine	Transparent	2633	14.8	15.6	0.5	0.6
Lead arsenate	Transparent	1588	21.4	79.9	1.3	5.0
Nicotine	Winesap	2501	29.6	20.6	1.2	1.0
Lead arsenate	Winesap	2496	74.4	653.5	3.0	25.8
Nicotine	Turley*	1300	81.2	16.2	6.6	1.4
Lead arsenate	Turley	909	58.3	202.7	6.5	22.7
Combination	Turley	1180	51.8	247.7	4.4	21.1
Nicotine	Ben Davis	754	130.5	67.4	17.0	9.0
Lead arsenate	Ben Davis	772	236.2	559.5	32.2	76.2

* Approximately 51 per cent of the fruit had dropped by June 30 in the lead arsenate area as compared to 8 per cent in the nicotine area, the difference being due to spray injury. Only apples remaining on the trees July 1 were used to provide the above records for this variety

Thus from the outset the nicotine treatment was given the disadvantage in location and previous infestation.

The spray treatments as applied to each area beginning with petal fall are outlined in table 4. Dosages are on a 100-gallon basis. Wyoming bentonite, in pellet form, was used.

Beginning with the second brood period, 37 acres in the nicotine area were diverted to a lead arsenate schedule. In order to minimize the loss in efficiency which results from such a change, this acreage was sprayed on June 29 and again on July 2 with lead arsenate at 3.2 pounds per 100 gallons; commercial copper fungicide, 0.6 pound; and mineral oil, 1 quart. The two final cover sprays were the same as those applied to the regular lead arsenate area.

Turley and Winesap varieties in the seven Winesap trees were selected in the nicotine and the lead arsenate areas in June to provide infestation data. In addition, seven Turley trees were selected in the area which was to receive the combination schedule. At harvest, eight Ben Davis trees in closely adjoining parts of the lead arsenate and nicotine areas were also utilized. Except for that of the Ben Davis, all drop fruit was scored. The first brood infestation on the Turley and Winesap varieties was determined on June 29 by examining "stratified" samples of 150 apples and all drops from each tree.

Results of Grower Test of Nicotine-Bentonite.—Moth abundance and activity as indicated by records from comparable bait traps were approximately equal in the two areas. An average of 59 moths per trap was caught during May

and June in the nicotine area and 57 per trap in the lead arsenate area. The average catches per trap for the entire season were 184 and 192, respectively, in the two areas. An increase in July which was expected in the nicotine area, because of the presence of 100 per cent more fruit, and the leaving of infested Transparent apples on the ground, did not materialize. The infestation records for the season are given in table 5.

The deposit building spray applied to the lead arsenate area May 31 caused a complete cessation of fruit growth for eight days on the Turley variety, after which a heavy drop of fruit began. Chemical analyses on June 1 showed an arsenic trioxide load of 47.3 mmg. per square centimeter. The injury may have been the result of oil too closely following after sulfur, of too heavy a deposition of oil or of too much arsenic. At the end of the first brood period, the fruit drop for this variety was 51 per cent of the total crop on the record trees as compared to only 8 per cent in the nicotine area. In addition, more or less injury to foliage occurred in the lead arsenate area. No injury whatever was observed in the nicotine area.

The nicotine deposit was seven weeks old when Turley harvest began (Sept. 17) and five weeks old when third brood larval hatch reached its peak early in September. Most of the codling moth injuries on all the winter varieties in the nicotine area were made in September, and it is apparent that nicotine sulfate should have been included with the 0.6 per cent oil spray applied to the nicotine area Sept. 1.

On the Turley variety, 43 per cent of the worm entrances in the nicotine area was located in or immediately adjacent to the calyx, while in the lead arsenate area only 9 per cent entered at that point. The Turley is a large apple, and, whereas early lead arsenate deposits would adhere in the deep calyx cavity after that end turned down, nicotine would continue to disappear. Apparently, in the last application, insufficient nicotine was deposited around the calyx of this variety. The same was true of the Ben Davis, but not of the Winesap, which is a smaller apple with a shallow calyx cavity.

Since the bentonite was used at 5 pounds per 100 gallons in all applications, the residue was conspicuous and could not be removed satisfactorily by brushing from the Turley, Ben Davis, Winesap and Rome Beauty varieties. Satisfactory removal was obtained by washing the fruit in an underbrush machine containing a solution of 40 pounds of sodium silicate and one-half gallon of mineral oil per 100 gallons. On the Transparent, the change to oil-nicotine in the fourth cover spray effectively masked and softened the bentonite deposit so that the necessity for cleaning was avoided.

Although laboratory-field tests have shown that oil-nicotine is far more effective as a larvicide when it follows nicotine-bentonite than when following lead arsenate, the oil loosens the bentonite, making it more susceptible to weathering and hence may have weakened the deposit on the fall and winter varieties. Repeated tests, however, have shown that substitution of oil-nicotine in the last spray or two before harvest on winter varieties is advisable if insurance against a too conspicuous bentonite residue is desired.

Although injury by leafhoppers had been severe throughout the entire acreage in 1936, the nicotine schedule almost completely eliminated damage by this insect in 1937. Leafhoppers, however, were very abundant in the lead arsenate area. A conspicuous difference in fruit color development favoring the nicotine treatment was evident early in September. Furthermore, Jonathan fruit with insufficient color began dropping more rapidly in the lead arsenate area prior to harvest. This difference in color development and in rate of drop was attributed in part to the heavy leafhopper population in the lead arsenate area.

The actual cost to the grower of spray materials applied for codling moth control after petal fall to Turley and Winesap apples averaged $1.17 per tree in the nicotine area and $0.69 per tree in the lead arsenate area. If we ignore the relative size of crops, which was greater in the nicotine areas on all varieties examined, the nicotine program cost 6 cents per bushel more for spraying the Turley, 3.7 cents per bushel more for the Winesap 8 cents more for the Ben Davis and 2.5 cents per bushel more for the Transparent. Despite low prices the nicotine program paid for its extra cost in increased clean fruit on all varieties except Turley. In addition the overwintering population was much lighter in the nico-

tine area, the cleaning expenses were reduced on all varieties (none for Transparent) and leafhopper damage as well as spray injury was avoided.

SUMMARY.—Under Midwest conditions deposits of lead arsenate sufficient for effective control of the codling moth are often more than the apple tree can stand.

Extensive tests over a period of three years have shown that a tank mixture of 1 pint nicotine sulfate, 5 pounds bentonite, 1 quart soybean oil, and one-fourth to one-half ounce sodium lauryl sulfate per 100 gallons is more effective than any other lead arsenate substitute tested. Combination laboratory-field tests showed that it equaled or was superior in larvicidal efficiency to the heaviest applications of lead arsenate that can be recommended for use in this area.

Commercial usage in 1937 on 90 acres in comparison with a heavy lead arsenate and lead arsenate-oil schedule on the remaining 122 acres of a local orchard gave the following results:

1.—Equal control of worms on one variety and reduction in worms up to 60 per cent on three others.

2.—Reduction in stings ranging from 88 to 96 per cent on all of the varieties.

3.—Excellent control of leafhoppers with greater early color development on all varieties and less drop of fruit on Jonathan.

4.—Complete avoidance of spray injury, whereas the lead arsenate schedule caused severe injury followed by a 50 per cent June drop of fruit on the Turley variety.

5.—Residue removal less difficult and less costly. No removal measures were needed on the Transparent and dry brushing was ample on the Jonathan.

6.—Its increased cost for materials was more than offset by the increase in uninjured fruit on all except the Turley variety.

7.—The high proportion of new entrances in the nicotine sprayed fruit in September indicated that the interval between the last nicotine spray (July 29) and harvest was too long. A nicotine spray was needed early in September.

The use of summer oil plus nicotine sulfate for the last two cover sprays will mask and soften the bentonite deposit and in most instances make unnecessary the cleaning of fruit at harvest.—1-15-38.

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Comparative Tests of Fixed Nicotines and Lead Arsenate Against Codling Moth*

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This report consists of information garnered in field studies of fixed nicotine compounds carried on in an orchard leased for the purpose at Mason, Mich. The objectives in these tests were to determine the toxicity under orchard conditions of promising fixed nicotine formulas to codling moth (*Carpocapsa pomonella* L.) and to apple trees; and to ascertain how such materials could be worked into spraying schedules such as are commonly used upon apple trees for control of insects and diseases.

CONDITIONS OF EXPERIMENTAL WORK.—The orchard in which this work was conducted consists of a section (160 trees) of old, low-vigor trees, mostly Spy, Baldwin, Ben Davis, Wealthy and Duchess, and a block (120 trees) of 16 year old McIntosh in vigorous condition. The McIntosh

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block permitted comparable toxicity tests with ample opportunity for adequate replication, and the older trees allowed extension of the tests, when desired, to trees of other varieties which were at a different level of vigor. The value of extending the tests is reflected in the moth control data recorded in tables 1 and 2 and in the observations on injury immediately following each tabulation.

Inasmuch as this orchard is isolated and was under our complete control, we were able to regulate the moth population by releasing moths and larvae. The inclusion of replications which received calyx and first cover sprays only is another desirable feature permitted by our control of the orchard.

METHODS.—The experimental work detailed is a progressive entity and the data are presented in chronological order. This permits illustration of the evolution of some of the more effective compounds which are lineally and directly derived from those compounds first reported by Driggers & Pepper (1934) according to the following scheme:

Bentonite-sulfur plus nicotine sulfate (1934).

Bentonite-nicotine sulphate, *B. L. 155* (8 per cent nicotine), 155 BX (8 per cent nicotine) (1937).

Nico Zin (20 per cent nicotine), *B. L. 155* A, B & C (all 8 per cent nicotine) (1937).

B. L. 1550 (13 per cent nicotine), *155 X* (8 per cent nicotine), and *155Z* (5 per cent nicotine) (1937).

B. L. 155. (B. L. 155Z) (5 per cent nicotine) (1937).

All of these materials are variations of the original bentonite-nicotine modified by the addition of various substances or variations in proportions of ingredients for the purpose of securing desirable qualities.

Fungous control in the experimental plots has been handled completely by timely and thorough applications of sulfur fungicides in the pre-blossom sprays. Combined applications of fixed nicotine compounds and fixed copper and of fixed nicotine compounds with elemental sulfur have been made to determine compatibility but the primary necessity for applications of fungicides in the post-blossom period has not arisen because of the excellent control from the timely pre-blossom spraying.

In determining the relative efficiency of the various fixed nicotine compounds, it has been the practice to confine tests to such numbers of materials and combinations as to allow random arrangement of replications in the block of McIntosh alluded to, thus permitting statistical treatment when desired.

In further tests of promising materials and combinations, the older block of trees has been divided into two or more large plots.

Spraying has been conducted in all cases upon a 10 day schedule (except lead arsenate in 1936) with a modern spray rig. The applications have been made at the rate of approximately one gallon of spray per bushel of fruit per application.

In the elimination of unsatisfactory materials and combinations it has been the practice to consider control first and allow considerations of type of codling moth injuries, retention, injury to foliage and fruit, visible residue and simplicity of formula to bear upon the final selection.

In accumulating the results of the experimental work here reported, all fruit in the plots was scored. Dropped apples were collected, scored and left beneath the trees from which they fell. This method permits, in addition to an accurate record of codling moth injury, opportunity for observation of fruit injury of all kinds.

EXPERIMENTS IN 1936.—Materials and combinations of materials selected as a result of previous work (Merritt 1937) were employed in the trials made during 1936.

All plots received calyx and first cover of lead arsenate plus the indicated number of cover sprays.

Treatments and results are apparent from table 1.

Those treatments receiving oil showed foliage drop and various fruit injuries. On Spy, russeted calyx and lenticel injury were common while on McIntosh russeted calyx was the common injury. Bentonite-nicotine (tank mixed) left a residue which could be removed only by scrubbing. Color did not develop well under the coating.

DISCUSSION OF 1936 RESULTS.—In the exceedingly high infestation obtaining in

Table 1.—Results of 1936 spraying tests in terms of injuries per 100 apples.

TREATMENT	VARIETY	WORMS	STINGS	TOTAL INJURIES
Lead arsenate, 3 lbs., and lime, 4 lbs., at 14 day intervals, 7 applications	McIntosh	99.35	75.65	175.0
	Spy	114.69	138.2	252.8
B. L. 155X, 5 lbs., 10 applications	McIntosh	117.51	20.03	137.45
	Spy	102.06	31.84	133.90
B. L. 155Z, 8 lbs., 10 applications	McIntosh	91.6	14.48	108.08
	Spy	84.66	28.31	113.07
B. L. 1550, 3 lbs., 10 applications	McIntosh	96.13	17.22	113.35
	Spy	113.61	40.99	154.60
Ortho Nicotine, 5 lbs., plus *Orthol K*, ½ gal., 10 applications	McIntosh	62.19	15.08	77.22
	Spy	122.11	40.55	162.66
B. L. 155X, 2 lbs., plus *Orthol K*, ½ gal., 10 applications	McIntosh	57.21	15.76	72.97
	Spy	57.94	41.48	99.42
Bentonite, 5 lbs., plus soap plus ¾ pt. nicotine sulphate, 8 applications, plus 2 applications *Orthol K*, ¾ gal., and ¾ pt. nicotine sulphate	McIntosh	54.07	21.87	75.94
	Spy	31.42	20.58	52.00
Check calyx and first cover, 3 lbs. lead arsenate	McIntosh	200.45	3.69	204.14
	Spy	246.56	21.74	268.30

the experimental plots during 1936 the most apparent single result is the superiority of fixed nicotine combinations applied on a ten day schedule when compared with lead arsenate on a 14-day schedule. This is true in every case except the number of worms present in McIntosh with the combination *B. L. 155X* used at the rate of 5 pounds per 100 gallons.

The value of 2 quarts of summer oil emulsion with fixed nicotine is another striking thing. *B. L. 155X*, 5 pounds, used alone as already noted did not result in particularly good control when compared to other fixed nicotine compounds. However, 2 pounds *B. L. 155X* plus 2 quarts *Orthol K* oil was one of the best mixtures

EXPERIMENTS IN 1937.—During 1937 the same experimental set-up was used as in 1936 except for minor deviations such as the deletion of lime from the lead arsenate sprays; the application of all sprays upon a 10-day schedule; and the exclusion of certain of the compounds tested in 1936, which were replaced by fixed nicotines and combinations suggested by the 1936 experiences. Biennial bearing in the older part of the orchard forced the use of the Baldwin variety instead of Spy in the tests upon older trees. All plots received calyx and first cover sprays of 3 pounds lead arsenate and 8 sprays of the indicated materials.

Table 2.—Results of 1937 spraying tests in terms of injuries per 100 apples.

TREATMENT	VARIETY	WORMS	STINGS	TOTAL INJURIES
Lead arsenate	McIntosh	2.1	31.8	33.9
(*B. L. 155=155Z*) *B. L. 155*, 8 lbs.	McIntosh	7.2	11.1	18.3
B. L. 155, 4 lbs., plus *Orthol K*, ½ gal.	McIntosh	3.0	9.3	12.3
	Baldwin	2.3	18.1	20.4
B. L. 155, 3 lbs., plus *Orthol K*., ½ gal.	McIntosh	4.2	8.7	12.9
Nicotine oleate, 1½ pt., plus Bentonite (fixator A), 5 lbs.	McIntosh	4.0	11.1	15.1
Check, calyx and first cover lead arsenate, 3 lbs.	McIntosh	53.0	13.3	66.3

The pertinent information collected during 1937 is presented in table 2.

The only noticeable spray injury in these plots was a slight calyx russeting of the fruit in the McIntosh plots sprayed with reduced dosages of *B. L. 155* plus ½ gallon oil. This injury, inconsequential with 4 pounds of *B. L. 155*, became more pronounced with 3 pounds of *B. L. 155* plus oil.

Nicotine oleate left a heavy persistent residue; other nicotine combinations left an inconsiderable residue.

Apples from these plots showed no signs of scab at harvest nor after being held in ordinary storage until December 1.

DISCUSSION OF RESULTS.—Inspection of the tabular presentation, supplemented by field observations, reveals that we may expect control from the use of the fixed nicotine compounds and combinations of these materials with oil; a control which is strictly comparable with the best results from combinations of lead arsenate and which obviates the necessity of washing. It seems apparent from the results attained that it is possible to balance fixed nicotine combinations in such a way as to permit in the same combination immediate and residual effects of such nature as to result in marked prevention of codling moth entries for a period of at least 10 days. The variations in control secured upon different varieties under closely similar conditions raises questions unanswerable from consideration of the difference in time of ripening and indicate that perhaps too much interest has been concentrated upon arriving at a measure of the time which should elapse between sprays to the exclusion of more applicable factors, such as rate of fruit growth and protection from scattered emergence early and late in the season. Attention upon the relation between coverage and growth rate early in the season is the next step in this study.

In a study of materials undertaken for the purpose of finding non-residue forming sprays, there seems little reason for continuing trials of materials such as tank-mix bentonite-nicotine (Merritt 1937) and nicotine oleate-bentonite (fixator) in their present forms. The presence of heavy, persistent residues from these materials in their present forms eliminates them from further consideration in non-washing schedules for standard varieties under our conditions. It will be noted that the oil-nicotine applications advocated for rendering these combinations have been applied.

The effect of the addition of one-half per cent oil to 4 pounds of bentonite-nicotine (*B. L. 155*) is a striking thing. The control secured from this combination cannot be explained altogether upon the basis of ovicidal effect from the oil although this must affect the results. Comparison of the effect of an 8 pound dosage of *B. L. 155*, with that resulting from the use of a 4 pound dosage plus oil, reveals an improvement in control appreciably better than can be explained solely on the basis of improvement in ovicidal effect, although this must be a part of the action. Certain evidence has been adduced (Marshall 1937) which suggests that perhaps the oiliness of particles results in better contact between them and the integument of the insect, thus increasing the chances that a larva crawling over a surface sprayed with the combination will encounter a poisonous dose. The incompatibility of this combination with sulphurs offers a slight objection to its use. This is of minor importance because the combination is compatible with fixed coppers and, as used in the reported tests, its application was started in the second cover spray, giving ample time for fungous control by sulphur on those varieties which are intolerant of copper.

Injury from this combination has been a minor consideration. The evidence gathered from comparisons of oil plus *B. L. 155* in 3 and 4 pound dosages apparently conforms to the generally accepted principle that increase of solids in sprays containing oil lessens chance of injury.

SUMMARY.—During two years, 1936 and 1937, fixed nicotines and combinations of fixed nicotines with other materials were tested in replicated plots on McIntosh, Spy and Baldwin. The controls secured under conditions of moderate to heavy infestation compare favorably with applications of lead arsenate included as a check. The fixed nicotines are increased in effectiveness by the inclusion of oils with them. This is especially true in the combination *B. L. 155* plus 2 quarts of summer oil emulsion.

Insofar as these experiments are concerned apple trees are remarkably tolerant of the fixed nicotines.—1-7-38.

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Recommendations for Control of Plum Curculio on Peach

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During the course of our studies of the plum curculio and other peach insects in Illinois, I have become increasingly interested in learning how these insects are controlled in other sections where spray schedules and practices differ, often quite radically, from our own.

FIG. 1.—Plum curculio sprays on peach.

Last spring, letters were written to entomologists in 19 other states in the eastern half of the country and in the province of Ontario, concerning similarities and differences in spray schedules. Copies of their recommendations, with comments, were received. In August a visit was made to a number of these states for the purpose of talking with some of the entomologists interested in peach insects and of visiting representative growers. This report concerns the control of one of the insects, the plum curculio, *Conotrachelus nenuphar* (Hbst.).

Spray recommendations in the several areas studied vary considerably in the following essentials: (1) the use of poison at petal fall, (2) the use of poison about a month before harvest, (3) the number of poison applications and (4) the strength of poison used.

USE OF POISON AT PETAL FALL.—In the following states, according to schedules received, a poison spray is used at petal fall for control of plum curculio: Alabama, Delaware, Georgia, Maryland, Mississippi, New Jersey, North Carolina, South Carolina and Virginia. In the following states, plum curculio spraying is begun at the "shuck" stage of peach when the shucks are one-half to two-thirds off: Arkansas, Illinois, Indiana, Kentucky, Louisiana, Michigan, Missouri, New York, Ohio, Pennsylvania, Tennessee and Ontario. Locating these states on the accompanying map, fig. 1, we find a strip of territory along the Gulf of Mexico and Atlantic Ocean including all the states from Georgia to New Jersey, in which peach spraying starts at petal fall. Directly west of them, often in adjacent states, is an area where spraying does not begin until shuck fall.

This difference is remarkable when we consider that the average time between the petal fall and the shuck stages, according to a five year record at Carbondale, Ill., was 16 days and in a sixth year was extended to 26 days. At Carbondale the same latitude as Richmond Va., 12 years of jarring records show very few curculios in the orchard before the shuck stage. Dr. C. O. Eddy's studies in Kentucky show the same condition in that state. On my visit to the East and South

I made it a point to satisfy myself, by talks with entomologists and growers who had actual jarring records, that the plum curculio does appear in the peach orchards there in sufficient numbers to justify the use of poison at the time of petal fall.

In this report I am offering no explanation but merely wish to point out the facts. It was difficult to decide just where these two areas met, but as far east as Knoxville, Tenn., Professor G. M. Bentley and growers who jar for curculio assured me that there is no need for a petal fall spray. As far west as Crozet, Va., there seems to be no question that spraying at petal fall is advisable.

USE OF POISON A MONTH BEFORE HARVEST.—The occurrence of increasing numbers of curculios approximately a month before the harvest of Elberta peaches is usually associated with moisture conditions which have allowed an appreciable number of beetles to emerge from pupation. It is associated also with a second brood which occurs regularly in parts of the South and to a lesser extent farther north. The only states of the 21 studied in which the beetles appear in such numbers that a poison spray at this time is regularly recommended are Alabama, Georgia, South Carolina, North Carolina and Tennessee. In Illinois and Missouri, the recommendation is to use this late spray only in years when curculio is abundant. In Illinois, this application has not been advised for eight years. The territory in which the late spray is used is shown on the map, fig. 1. It will be seen that this late application is not advised over all of the south, as Mississippi, Arkansas and Louisiana do not recommend it. A study of this problem is at present being conducted in Louisiana, and the recommendation may be changed there.

NUMBER OF POISON APPLICATIONS.—There is much variation in the number of poison sprays advised. In Illinois, jarring over a period of years in unsprayed orchards, not affected by any control measures, has shown that (1) only a small per cent of the beetles has emerged from winter quarters and flown to the orchard by the time of the shuck stage, (2) that a larger per cent of them is found in the orchard at the time we recommend the second spray, which is 10 days after the shuck stage and (3) that many others do not appear until the time for the third spray, which is two weeks after the second. For this reason we recommend these three applications except in very light curculio years when we send special notices to growers suggesting the elimination of one or possibly two sprays. A study of the 21 spray schedules received shows that in seven of them two or less applications are advised and that in three of these seven, New York, Ohio and Ontario, only one. The only logical explanation for this situation that has been suggested is the light infestation normally existing.

STRENGTH OF POISON USED.—The difference in strength of lead arsenate recommended is partly accounted for by the degree of infestation and partly by occurrence or fear of arsenical injury. In Missouri and Illinois, 3 pounds to 100 gallons are recommended. In Louisiana, $2\frac{1}{2}$ pounds are advised, but elsewhere 2 pounds is the regular strength except in Indiana where only 1 pound is used. In Illinois we normally get very little injury with 3 pounds when zinc sulfate plus lime is used, and, as we often have considerable curculio with 3 or 4 sprays of this strength, we do not feel it advisable to lower the amount. We think there is a need for a study of control obtained by 2 pounds compared with 3 pounds when zinc sulfate is used as a safener.

In the foregoing paragraphs, I have discussed four essential points in which there is much difference in spray recommendations for the principal peach areas of the eastern United States and Canada. My thought is that because of these sharp contrasts in control practices in adjacent areas and unexplainable differences in the activities of the insect, there is a real need for the various states to carry on investigations to determine the situation in their own peach areas without regard to what is considered proper in some other sections.—1-7-38.

THE STATE OF VIRGINIA on February 25 placed a new quarantine relating to sweetpotato weevil requiring certification of host material as free from any danger of spread of the weevil, when shipped from any part of Alabama, Florida, Louisiana, Mississippi, Texas or from five designated counties in Georgia. The quarantine does not conform to the standardized draft.

Experiments in the Control of Oriental Fruit Moth with Oil Dusts

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Oil dusts were first used for the control of oriental fruit moth, (*Grapholitha molesta* (Busck.), in southern Illinois peach orchards during the season of 1929. The results were promising. In fact, they were better than results from any of the other insecticides which we had tried. Since that time, tests have been run every year when there was a sufficient peach crop to warrant the carrying out of insecticidal orchard test plots.

The dusts have been somewhat improved from year to year. The results to date have been so favorable that many Illinois growers have adopted the use of oil dusts as a means of controlling oriental fruit moth in their commercial peach orchards. All of our tests have been run on peach varieties maturing about the season of the Elberta. No attempt has been made to control the oriental fruit moth on late season varieties.

Table 1.—Results of spray treatments in Graves Orchard, Villa Ridge, Ill., 1929.

Treatment	Per Cent Curculio Infestation	Per Cent Oriental Fruit Moth Infestation	Per Cent Efficiency in Control of Oriental Fruit Moth
Oil dusted plot	5.0	5.1	80
Standard dust plot	10.1	19.8	20
Control	31.5	24.5	

Dust Formulae.—At the present time we are suggesting the following formulae as the best to use in making the dust:

Early Season Dusts.—(Should not be applied within 30 days of picking time.)

30 lbs. sulfur (300 mesh, dusting grade)
25 lbs. hydrated lime
30 lbs. talc (300 mesh)
10 lbs. lead arsenate
5 lbs. oil (Saybolt 104, 100 degrees F., unsaturated)

Late Season Dusts.—

60 lbs. sulfur (300 mesh, dusting grade)
15 lbs. hydrated lime
20 lbs. talc (300 mesh)
5 lbs. oil (Saybolt 104, 100 degrees F., unsaturated).

Summary of Results.—The following is a brief summary of the experimental tests, year by year, covering the period from 1929 to 1937.

1929.—Oil dusts were first used in the Graves Orchard at Villa Ridge, Ill., during the summer of 1929. Results are shown in table 1.

1930.—Oriental fruit moth was greatly reduced by the cold weather of the winter of 1929–30, and the peach crop was reduced to such an extent that no experiments were possible that year.

1931.—Extensive tests were arranged for this season, and a series of plot treatments was carried out in three orchards. The infestation was so light that the data from these tests were of no value, the check plots having only a fraction of one per cent infestation by the oriental fruit moth.

1932.—In this year plots were run in two orchards where sprays and oil dusts were compared. There was little differ-

Table 2.—Results of spray treatments in Chandler Orchard and in Thomas Orchard, Carbondale, Ill., 1932.

Treatment	Per Cent Curculio Infestation	Per Cent Oriental Fruit Moth Infestation	Per Cent Efficiency in Control of Oriental Fruit Moth
Chandler Orchard			
Sprayed plot	7.0	8.9	79
Oil dusted plot	4.8	10.0	76
Control	5.8	42.0	
Thomas Orchard			
Sprayed Plot	2.5	16.7	58
Oil dusted plot	2.7	17.4	58
Control	24.8	40.8	

Table 3.—Results of spray treatments for oriental fruit moth, 1935.

PLOT NO.	TREATMENT		PER CENT ORIENTAL FRUIT MOTH INFESTATION	PER CENT EFFICIENCY IN CONTROL OF ORIENTAL FRUIT MOTH
	First of Season	Last of Season		
1	2 sprays, lead, lime, zinc sulfate. April 29; May 15	2 wettable sulfur sprays. July 20; August 2	40.2	23.9
2	Oil dust with lead. April 29; May 15 (1 lb. per tree, ½ lb. from each side)	3 oil dusts without lead. July 8, 20; August 2. Dusted from both sides (1 lb. per tree, total)	34.5	34.7
3	Same as Plot 2, but dusted from one side only (½ lb. per tree)	Same as Plot 2, but dusted from one side only (½ lb. per tree)	28.3	46.4
4	Same as Plot 1	Same as Plot 2	26.9	48.1
5	Same as Plot 1	Same as Plot 2, but containing derris	32.8	37.9
6	Control (no application)	Control (no application)	52.8	

ence in that season between the control obtained with dusts and that obtained with sprays. Results are shown in table 2.

1933.—There was a very light and scattered crop in this year and no experiments on oriental fruit moth control were attempted.

1934.—A freeze in February killed nearly the entire peach crop of the state. No experimental work on oriental fruit moth was done. Some growers who had a light crop on high land reported good results from the use of oil dusts.

1935.—The weather of 1935 was very favorable for the development of the oriental fruit moth. Our experimental results for this year are shown in table 3.

Table 4.—Results of spray treatments in orchards at Anna and Villa Ridge, Ill., 1936.

TREATMENT	PER CENT CURCULIO INFESTATION	PER CENT ORIENTAL FRUIT MOTH INFESTATION	PER CENT EFFICIENCY IN CONTROL OF ORIENTAL FRUIT MOTH
ANNA ORCHARDS			
6 applications of oil dust	0.4	0.4	97
4 applications of oil dust	0.5	3.3	75
Orchard no. 1, oil dust (owner's application)		0.4	97
Orchard no. 2, oil dust (owner's application)	0.2	1.0	92
Control (no application)	20.0	13.1	
VILLA RIDGE ORCHARD			
4 oil dusts (owner's application)	1.1	2.0	80
2 sprays during month before harvest (owner's application)	5.0	6.2	60
Control (no application)	15.2	10.2	

During this season only three preharvest dusts were applied. This treatment was not enough to give the best control.

1936.—In this year the peach crop was light and confined to the ridge or high ground orchards in the southern part of the state. The oriental fruit moth infestation was moderate in all sections. Four series of tests were carried out in which oil dusts were used, and good control of oriental fruit moth was obtained in all these tests.

In large commercial orchards at Anna and another orchard at Villa Ridge, the results which are shown in table 4 were obtained.

1937.—During this season oriental fruit moths were about as numerous as in 1936. Test plots run in orchards at Carbondale and Tunnel Hill, Ill., gave the results shown in table 5.

Table 5.—Results of spray treatments in orchards at Carbondale and Tunnel Hill, 1937.

TREATMENT	PER CENT CURCULIO INFESTATION	PER CENT ORIENTAL FRUIT MOTH INFESTATION	PER CENT EFFICIENCY IN CONTROL OF ORIENTAL FRUIT MOTH
4 oil dusts, starting three weeks before peach harvest	1.7	5.1	69
4 sprays with fixed nicotine, starting three weeks before harvest	7.6	12.6	25
Control (no application)	8.8	16.1	

Table 6.—Results of tests in Tunnel Hill, Ill., orchard with mixed planting of apples and peaches, 1937.

TREATMENTS	PER CENT ORIENTAL FRUIT MOTH INFESTATION	PER CENT EFFICIENCY IN CONTROL OF ORIENTAL FRUIT MOTH
Plot sprayed with a fixed nicotine experimental mixture	27.0	0
Plot dusted with five homemade oil dusts (not suggested formula)	7.8	70

The tests in the Tunnel Hill orchard with a mixed planting of apples and peaches gave the results shown in table 6.

OBSERVATIONS IN GROWERS' ORCHARDS.—In addition to the results presented from our experimental orchards, we have many observations in growers' orchards. In many cases the growers' results have been better than those from the experimental plots.

Because our tests show no increased control of oriental fruit moth by the use of oil dust early in the season, these applications should be put on only when needed for plum curculio. For the oriental fruit moth, four late season applications of oil dust should be made, starting about three weeks before harvest and ending two or three days before picking begins. It is during this period that most of the oriental fruit moth infestation occurs.—1-7-38.

The Strawberry Leaf Roller, *Ancylis comptana* (Froel.), in Ohio

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It has been known for many years that the strawberry leaf roller, *Ancylis comptana* (Froel.), is widely distributed throughout the state of Ohio, but previous to 1935 it had not been considered of much economic importance. The correspondence files of the Department of Entomology of the Ohio Agricultural Experiment Station reveal but 14 records during the 45 year period previous to 1934.

A definite leaf roller outbreak occurred in southwestern Ohio in 1934, and the population continued to increase during the two seasons following. Some untreated plantings in 1936 produced less than half a crop as a result of the severe injury, and counts showed as much as 76 per cent of the leaflets damaged. The infestation was centralized in Montgomery, Miami and Butler counties. During the season of 1937 the damage appeared somewhat less severe in these counties, but a severe outbreak appeared in Ashland County in the northcentral part of the state.

LIFE HISTORY.—The life history of the strawberry leaf roller was studied in the Wooster insectary during the seasons of 1936 and 1937. The records obtained were based on 82 breeding cages, into each of which was introduced a single pair of moths. Observations were made on 4976 eggs, 1339 larvae, 141 pupae and 1444 moths reared to adulthood from the entire set-up.

Two complete generations and a partial third appeared during both seasons. All of the third brood of larvae and part of the second sought hibernation. Moths of the spring brood emerged during May; those of the first brood, during July and the fore part of August; and those of the second brood, during the latter part of August and the first few days of September.

The average number of eggs laid by one female in breeding cages was 80 for the spring brood, 53.3 for the first brood and 42.6 for the second brood. The maximum number laid by one female was 158. The average length of the incubation period was 10.8 days for eggs of the first brood, 8.6 for the second and 7.8 for the third.

The length of the combined larval and pupal periods of the first generation averaged 40 days and of the second generation, 35.3 days. The average developmental period of the first brood pupae was 9.5 days and of the second brood, 9.3 days. It will be noted that as the season advanced and the weather became

warmer, the life cycle became shorter. It is also true that female moths lived longer and laid more eggs during the early part of the season, and that in the field the greatest damage was caused by the first brood of larvae.

PARASITIZATION.—The larval parasite, *Macrocentrus ancylivorus* Roh., which attacks both the strawberry leaf roller and the oriental fruit moth, was not known to be present in southwestern Ohio previous to 1935. On July 24 of that year a colony was released in Montgomery County in a strawberry planting which adjoined a peach orchard. This colony multiplied rapidly and during 1936 and 1937 proved a very effective parasite of the fruit moth in that locality. A collection of oriental fruit moth larvae infesting peach twigs, taken September 1, 1936, was 97 per cent parasitized by *M. ancylivorous*. In 1937 this species accounted for 95 per cent of the total fruit moth parasitization found in Montgomery County.

Parasitization of the strawberry leaf roller, however, has not been so encouraging. During 1937, only 6.4 per cent of the larvae collected in Ohio was parasitized, and, although *M. ancylivorus* is known to be present in each county studied, it accounted for but 21.2 per cent of the parasitization. *Cremastus cookii* Weed was found to be the most effective parasite and was obtained in each county in which leaf roller larvae were collected.

Table 1.—Injured strawberry leaflets in a 600 leaflet sample, June 10, 1936.

MATERIALS*	NO. OF APPLICATIONS	REPLICATIONS					MEAN	PER CENT CONTROL
		1	2	3	4	5		
Derris, 4 per cent rotenone, 12½ lbs. Gypsum, 87½ lbs.	3	122	73	124	135	100	100.8	75.7
Cubé, 4 per cent rotenone, 12½ lbs. Gypsum, 87½ lbs.	3	197	276	243	246	244	241.2	47.2
Black Arrow Dust	3	215	254	256	240	260	245.0	46.3
Dutox, 5 lbs. *Grasselli Spreader-Sticker*, 100 cc. Water, 100 gal.	2	233	310	284	286	200	262.6	42.5
Kalo Spray, 5 lbs. *Grasselli Spreader-Sticker*, 100 cc. Water, 100 gal.	2	74	170	111	78	118	110.2	75.9
Check, no treatment	0	383	503	416	502	478	456.4	—

CONTROL STUDIES OF 1936.—Growers in southwestern Ohio tried a lead arsenate treatment for the control of the leaf roller during the seasons of 1934 and 1935 but reported poor success. Consequently, a project for the control of this insect was inaugurated in that area in 1936. Sixteen insecticidal treatments were tested against the first brood and each was replicated five times. Plots were three rows wide and approximately 30 feet long. Applications were made May 11–12, May 21–22 and May 27. At the time of the third application, the use of some materials was discontinued and only those were used which would not leave a poisonous residue on the berries.

Differences in the damage recorded in the various plots on May 21 were not significant, but these differences increased as the season advanced. In detailed counts made on May 27 several treatments appeared so much superior to lead arsenate that no further records on the lead plots

* The materials listed in tables 1 and 2 are presented under their trade names. The effective ingredients and the manufacturer of each are as follows:

Black Arrow Dust—pyrethrum; McCormick & Co., Baltimore, Md.

Dutox—barium fluosilicate and sodium fluoaluminate; E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.

Kalo Spray—natural cryolite; The Kalo Company, Quincy, Ill.

Kryocide—natural cryolite; Pennsylvania Salt Mfg Co., Philadelphia, Pa.

Alorco—synthetic cryolite; Aluminum Ore Co., East St. Louis, Ill.

Red Arrow—pyrethrum; McCormick & Co., Baltimore, Md.

Dry Pyrocide—pyrethrum; McLaughlin Gormley King Co., Minneapolis, Minn.

Orthol K—summer spray oil; California Spray-Chemical Corporation, Berkeley, Calif.

Grasselli Spreader-Sticker—sulfated alcohol; E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.

were taken. On June 10, 600 leaflets in each of the plots treated by the more effective materials were examined for leaf roller injury. The data obtained are presented in table 1.

Two applications of a formula composed of *Kalo Spray* and *Grasselli Spreader-Sticker* proved just as effective as three applications of one consisting of powdered derris root dust. These two formulae were significantly better than any other treatment used. All of the plots so treated were so free from injury that they could be detected readily without consulting the label stakes.

CONTROL STUDIES OF 1937.—In 1937, early observations indicated that no appreciable injury was likely to develop in Montgomery County, but larvae appeared rather suddenly nearly two weeks later in the season than in 1936. Folded leaves became sufficiently abundant to cause the growers considerable alarm. Consequently, on June 3 and 4, several materials were used in one application on small replicated plots. The berries were ripening at that time and, consequently, the tests were limited chiefly to non-poisonous materials. However, two fluorine treatments were included. A 10 acre area of the planting which was not included in the experimental plots was dusted by the grower with a commercial material containing 0.75 per cent of rotenone.

Counts were made in the experimental plots and also in the 10 acre area on June 17. It was found that *Red Arrow*, *Kalo Spray* and *Dry Pyrocide Dust* had each effected more than a 50 per cent control,

Table 2.—Injured strawberry leaflets in a 600 leaflet sample, August 18, 1937.

MATERIALS	REPLICATIONS					MEAN	PER CENT CONTROL
	1	2	3	4	5		
Kalo, 5 lbs. *Grasselli Spreader-Sticker*, 2 oz. Water, 100 gal.	0	4	40	16	11	14.2	89.3
Alorco, 5 lbs. *Grasselli Spreader-Sticker*, 2 oz. Water, 100 gal.	2	13	9	19	6	9.8	92.6
Red Arrow, 2 pts. *Orthol K*, 4 pts. Water, 100 gal.	33	33	12	58	34	34.0	74.3
Phenothiazine, 3 lbs. Water, 100 gal.	95	73	42	64	21	59.0	55.4
Alorco, 1 part Talc, 2 parts Flour, 2 parts	10	10	16	10	12	11.6	91.2
Dry Pyrocide, 1 part Talc, 9 parts	34	32	16	28	43	30.6	76.9
Kalo, 1 part Talc, 2 parts Flour, 2 parts	11	6	4	9	6	7.2	94.6
Dutox, 1 part Talc, 2 parts Flour, 2 parts	3	16	1	4	8	6.4	95.2
Kalo, 3 parts Talc, 6 parts	5	20	13	8	4	10.0	92.4
Kryocide, 1 part Talc, 2 parts Flour, 2 parts	5	4	10	8	2	5.8	95.6
Check, no treatment	171	119	82	220	70	132.4	—

but the differences among these materials were not sufficient to be considered significant. Although the injury was much lighter than in 1936, each of the above mentioned materials proved more effective than powdered derris root; likewise, than the rotenone dust applied by the grower in the larger block.

Tests against the second brood were conducted in a heavily infested planting in Ashland County. The experimental arrangement was similar to that of 1936 in that the plots were approximately the same size, and the treatments were replicated an equal number of times. Ten treatments and a check were employed and three applications were made at weekly intervals beginning July 15, when the first second-brood eggs were hatching.

Seven of the 10 insecticidal treatments included fluorine as the toxic agent. At the time of the third application these materials showed a control of from 80 to 87 per cent when compared with the untreated plots. No significant differences among them were evident, but all appeared more effective than the three remaining materials.

Eighteen days after the third application, injured strawberry leaflets were counted in a 600 leaflet sample taken near the center of each plot. The record obtained is shown in table 2.

It will be observed that all of the fluorine combinations were effective whether used as dusts or sprays. The differences in control produced by the several fluorine formulae were not sufficiently great to be significant. All treatments with fluorine were significantly better than was that with phenothiazine. Those that yielded best results were significantly better, at odds of 19 to 1, than either *Dry Pyrocide* or the *Red Arrow* plus oil combination.

The part of the planting not included in the experimental plots comprised approximately three-fourths acre. This area was sprayed with the first formula listed in table 2. Leaf counts made in this area on August 18 showed a very effective control. Less injury was evident than in any of the small replicated plots.

CONCLUSIONS.—The results of the work of two seasons indicate that the use of either natural or synthetic cryolite is a very effective control for the strawberry leaf roller. Both natural and synthetic cryolite appear equal in effectiveness and may be used in either dust or spray form. The use of a spreader is advisable in spray applications, especially if a considerable number of leaves is folded at the time of treatment. The foliage should be well covered when the first eggs are hatching, and coverage should be maintained during the period that larvae are actively feeding. Three applications at weekly intervals largely cover the activities of one brood. In the Ohio experiments this program effected a commercial control.

Seasonal conditions involving both the insect and the crop may limit the preharvest treatments to two or even one because of residue complications. If this hazard develops and an additional treatment is needed, *Dry Pyrocide Dust* may be substituted for cryolite in the application immediately preceding harvest. In all instances of serious early season damage, a vigorous post-harvest program of fluorine treatments should be executed if the planting is permitted to stand.—4-21-38.

Biology and Control of the Strawberry Crown Borer, *Tyloderma fragariae* (Riley), in Kentucky*

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The strawberry crown borer, *Tyloderma fragariae* (Riley), for the past forty years has been the worst insect pest with which Kentucky strawberry growers have had to contend. The most serious outbreaks occurred in western Kentucky. At present, the worst infestation is found in McCracken and adjoining counties where it is estimated that the pest caused $100,000 damage in 1936.

In the fall of 1936, at the request of

* The investigation reported in this paper is in connection with a project of the Kentucky Agricultural Experiment Station and is published by permission of the Director.

growers, the Kentucky Agricultural Experiment Station set up a project on strawberry crown borer in western Kentucky. This progress report is based mainly on field work in McCracken, Caldwell and Lyon counties.

LIFE HISTORY.—By detailed rearing work, the strawberry crown borer was found to have two generations during 1937 in western Kentucky.

The great majority of crown borers passed the winter of 1936–37 under trash in infested patches. A very few passed the winter as larvae within infested plants and matured in February and March. During the warm days in February and March, when the maximum daily temperatures were 55 degrees F. or above, overwintering beetles became active and fed on strawberry foliage, fig 1.

Adults which had hibernated began to oviposit early in March and continued to lay eggs through August. The first larvae hatched in April. In September some first generation larvae could still be found tunneling through strawberry crowns. Pupation of first generation larvae began the middle of June. First generation adult crown borers began emerging the third week in June and continued through October. The majority of the first generation adults emerged in July and August.

Some of the earliest, first generation adults began laying eggs late in July, continuing into September. These eggs gave rise to second generation larvae, most of which became adults the same fall and left the berry crowns.

The many first generation beetles and the fewer second generation beetles fed on strawberry foliage in the fall. According to Marcovitch (1923) certain adults hibernate a second winter and lay eggs a second year. Pairs of beetles are being overwintered to determine this point.

Eleven pairs of adults which had hibernated were kept in an insectary. These laid from 29 to 102 eggs and averaged 62.7 eggs per pair during the season of 1937. Three pairs of early first generation adults laid 4, 7 and 8 eggs.

Eggs laid in the spring were very slow in hatching. During June, July and August, the incubation period averaged about ten days. The length of the larval stage in midsummer was approximately 20 days. The larvae passed through five instars. The length of the pupal stage varied from 8 to 11 days during June, July and August.

EGG LAYING.—It was concluded from detailed observations in the vicinities of Princeton and Paducah, Ky., that no crown borer eggs were laid until early in

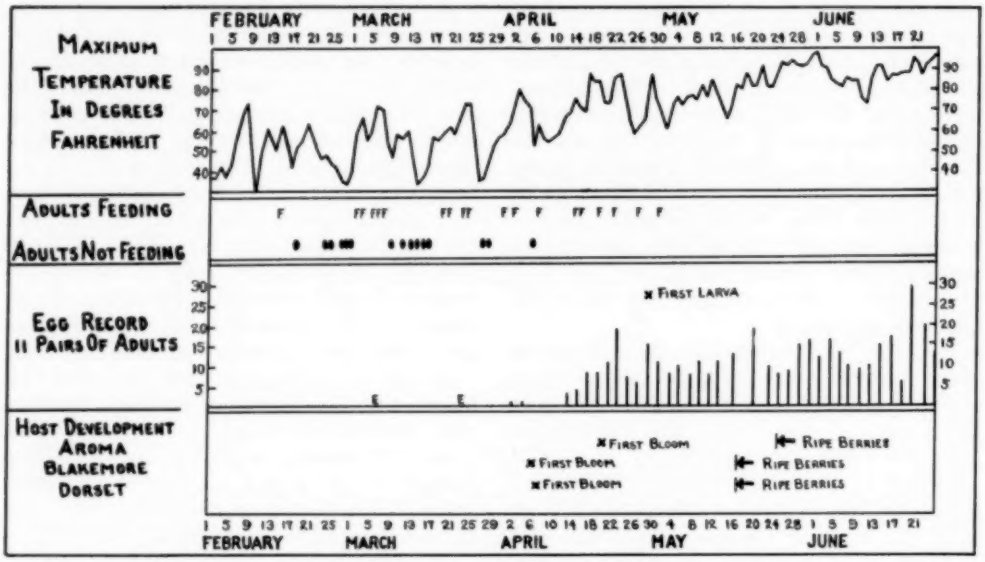

FIG. 1.—A graphic summary of records correlated with the spring activity of the strawberry crown borer *Tyloderma fragariae* (Riley).

March, fig. 1. Few eggs were laid before the first of April in 1937. Eggs were not laid in numbers until the middle of April. At this time, Blakemore and Dorset varieties of plants were just beginning to bloom at Princeton.

Crown borer eggs were always laid in or on the strawberry plant. They were usually deposited in shallow excavations and covered with dirt and bits of tissue gnawed by the female from nearby areas.

Eggs were deposited most commonly in excavations made in the wide leaf bases of the strawberry plants, down toward the origin of the lateral roots and close to the soil surface. The excavations often cut through the stipular areas of several old leaf bases and often did not penetrate the crown proper.

Some eggs were merely tucked in behind the dead tissue of the old leaf bases. Othere were deposited in the crown itself below the origins of the uppermost lateral roots and below the surface of the soil. A few eggs were laid in the lateral roots.

INJURY.—The main damage of the strawberry crown borer is caused by the larvae, which tunnel through the strawberry crowns. In experimental plots, 55 per cent of the infested Aroma plants died outright or were badly stunted by early August. Forty-five per cent of the infested plants, by early August, showed little effect themselves but suffered a reduction in the number of runners put out and plants set.

One-year strawberry patches, when heavily infested with crown borer, have only a partial stand of plants, part of which have been retarded in their growth. This results in a reduced yield of berries the next year even though most of the runner plants are uninfested. By the second year such a patch is usually so full of crown borer that it it not worth picking.

HOST PLANTS.—Besides the cultivated strawberry, the strawberry crown borer was found breeding in the wild strawberry, *Fragaria virginiana* Duchesne, and in common cinquefoil, *Potentilla canadensis* L. Common cinquefoil abounds in western Kentucky and was found infested with crown borer even in areas where strawberries were not grown. It would appear that the crown borer is native on this wild host in Kentucky. Much of the crown borer infestation in strawberry patches was traced to nearby cinquefoil.

PARASITES AND PREDATORS.—The strawberry crown borer in Kentucky is Kentucky is attacked by several insect parasites and predators. The larvae of *Microbracon analcidis* Ashm. were found parasitising about 2 per cent of the crown borer larvae examined during the season of 1937. One larva of *Hister americanus* Payk. was found at Princeton, consuming a large crown borer larva. A number of elaterid larvae were found feeding on crown borer larvae or pupae. Two of these were reared and identified as *Monocrepidius auritus* Herbst.

SAFE DISTANCES FOR NEW PLANTINGS.—Adult crown borers cannot fly because their hind wings are vestigial. This means that the adults, unless carried, must reach new breeding grounds by crawling. How far crown borer adults can crawl in the absence of food plants has an important bearing on the distance new patches must be placed from old patches and other breeding places to prevent infestation.

Marking experiments carried on in 1937 showed that crown borer adults can travel considerable distances by crawling. In all, 1038 marked adults were released at varying distances from a strawberry patch and recovery collections were made. Of 160 blue-marked beetles released at 125 yards, seven were recovered. Of 612 gray-marked beetles released 300 yards distant, one was recovered.

Adult crown borers lived at least 16 to 19 days when deprived of food but given moisture. This fact, coupled with the fact that one marked adult traveled at least 125 yards in a little less than three days, gives some idea of the maximum distance crown borer adults can crawl even in the absence of food plants.

For practical purposes, it should be safe to plant new strawberry patches at a distance of 350 yards from a source of infestation. If a new patch cannot be set 350 yards from a source of infestation, it should be set as far away as possible.

WHERE TO SET NEW PATCHES.—Strawberries should be set only on land that has been cultivated for one or more years. Tobacco was found to be a good crop for strawberries to follow. It is not safe, as a rule, to plant strawberries on or near land where berries have been grown the previous year, since growers, when plowing, often leave infested plants

or overlook such plants around the edges of old patches.

TREATMENT OF OLD PATCHES.—Old strawberry patches should be plowed up immediately after the last picking, disked, dragged once or twice and sown to another crop. Fall and early spring are poor times to plow up old patches. It is almost impossible to get rid of all the plants at these seasons, and crown borer continues to breed.

SELECTION OF PLANTS.—It has been found possible to take plants from even heavily infestated berry patches and free them of crown borer by digging and cleaning the plants prior to March 1, before any eggs are laid. Under ordinary farm conditions, the best way for a grower to start a borer free patch is to use only certified plants from inspected patches.

DESTRUCTION OF WILD HOSTS.—Some Kentucky growers who have borer infested cinquefoil on their farms could get rid of it by cleaning up their fence rows or ditches. Digging up and burning the cinquefoil, crowns and all, is the best method of destruction.

CROWN BORER BARRIERS.—When a berry producing area is full of crown borer and infested wild host plants, as is McCracken County, Ky., it will prove difficult for many growers to start borer free patches at any safe distance from sources of infestation. In such cases, a suitable barrier would make it possible for growers to set new patches close to old ones and infested wild hosts.

Preliminary tests indicate that one type of easily constructed barrier may turn back adult crown borers. This barrier consists of a continuous strip of rough sawn boards, 1 inch × 6 inches × 10 feet, set on edge around the patch. The boards are fastened in the middle and at the ends to 2 inch × 2 inch stakes and are driven into the soil to a depth of 2 or 3 inches. To the top of each board and turned outward is fastened an L-shaped strip of galvanized iron. Field tests with barriers are now in progress.—4-18-38.

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A Method for Measuring Effects of Dormant Sprays upon Apple Tree Growth[1]

JOHN H. LILLY,[2] *University of Wisconsin, Madison*

A significant trend in recent entomological field work seems to be toward more careful consideration of the effects of insecticidal programs upon the treated host plants. The need of standardized quantitative methods for the study of such effects by different investigators and under different conditions is clearly evident. This paper presents such a method for recording the effects of dormant sprays upon development and growth of apple trees.

Many workers have noted visible deleterious effects following the application of dormant oil sprays on fruit trees. Severa of them have used more or less quantitative methods for measuring and evaluating these effects. On the other hand, certain writers have called attention to a stimulating influence of dormant oil treatments under some conditions. Only a few representative papers can be cited here.

PREVIOUS BUD INJURY STUDIES.—The most common and important dormant oil effects on fruit trees involve the buds. Both leaf and fruit buds may be affected. Regan (1923) described significant oil injuries as a retardation of foliage development in early spring and the outright killing of buds. He stated that the retarded development made these trees detectible several weeks after the rest of the block had come into full foliage, and that they could be differentiated even late in the season by a thinner foliage output,

[1] This paper is published with the approval of the Director of the Wisconsin Agricultural Experiment Station.

[2] The writer wishes to express his sincere appreciation to Prof. R. H. Roberts of the Department of Horticulture, University of Wisconsin, who originally suggested this method and made several useful contributions during its development, and to Dr. Churchill Eisenhart of the Statistical Service of the College of Agriculture who gave valuable advice in working out the mathematical phases.

due to the number of buds killed. Spuler and his co-workers (1931) suggested that these two effects are really differences in degree by these words: "Oil injury to leaf and spur buds will vary from a delayed growth of foliage to a complete killing of buds." They stated further that "the trees will outgrow the former condition, but the latter condition will result in permanent injury as no new buds replace the buds killed." Farrar & Kelley (1935) reported retardation of bud opening by dormant applications and the killing of

Oil Spray Data Page 14

Location ORCHARD A Plot CONTROL Treatment UNSPRAYED

Remarks _____ By J.H.L. Date 8-22-36

Length of Count-Wood								Length of Count-Wood							
4	5	6	7	8	9	10	11	4	5	6	7	8	9	10	11
1	3	5	7	8	7	10	9	2	3	6	8	7	9	10	13
4	5	6	6	4	8	7	10	5	4	6	7	8	8	7	9
4	5	7	5	6	8	9	8	4	3	3	6	8	7	10	10
3	4	6	6	5	9	7	8	2	5	4	5	6	7	10	7

FIG. 1.—Heading of blank form used to collect the data discussed in the text, including some of the values (numbers of growing buds on individual count-units) observed. Fifty counts were made for each length in each plot. In Wisconsin this necessitates a minimum of about 15 count-trees per treatment.

terminal and lateral buds by delayed dormant sprays.

It should be pointed out that severe injuries described by these and other writers usually have been due to misuse of dormant oils, often with the express purpose of studying injuries. Where they are common and severe there can be little doubt regarding their importance. It sometimes happens, however, that similar effects are present in a much smaller degree where dormant oil sprays are applied experimentally or commercially. When such is the case it is logical to attempt a quantitative estimate of the extent and importance of the injury.

Various investigators have developed more or less satisfactory quantitative procedures for measuring the effects of dormant oil sprays on fruit trees. Some of them (Austin, Jary & Martin 1935; Gentner & Norris 1933) have made careful and extensive observations and published detailed notes, often supplementing their writings with photographs. Others have set up arbitrary classes into which varying degrees of injury could be catalogued (Harman 1928; Young & Morris 1933). Still others have made extensive bud counts and expressed their results as per cent of buds injured by the treatments in question (Gentner & Norris 1933; Overly & Spuler 1928; Overly 1929; Ross 1931). Austin *et al.* (1933) presented a table showing the "average number of blossom trusses per yard of wood of branches selected at random from each tree." Several writers (Overly & Spuler 1928; Overly 1929; Ross 1931; Spuler *et al.* 1931) have given fruit set or yield data. Farrar & Kelley (1935) made detailed records of twig growth by measuring length, circumference and square inches of bark, and followed tree growth by measuring height and trunk circumference. The last named workers and also Ross (1931) studied cumulative effects of annual treatments over periods of from 4 to 10 years. At least two workers in this field have used statistical procedures to test the significance of their results (Austin *et al.* 1933; Overly & Spuler 1928).

METHOD OF PROCEDURE OF PRESENT STUDY.—The following method of measuring the effects of dormant oils has been developed by the writer and used in Wisconsin for the past five years with consistently satisfactory results. One-year-old wood ranging in length from 4 to 11 inches is used as count-wood. Terminal growths of the previous growing season are selected at random on all sides of the experimental trees, so as to get samples

sprayed from all angles. The length of each count unit is then measured and the number of buds on it which have put out two or more leaves is recorded, regardless of the leaf area produced. Data are kept on a mimeographed blank form. Fig. 1 shows the heading of such a blank form and some sample figures. Similar counts on unsprayed trees are made for a basis of comparison.

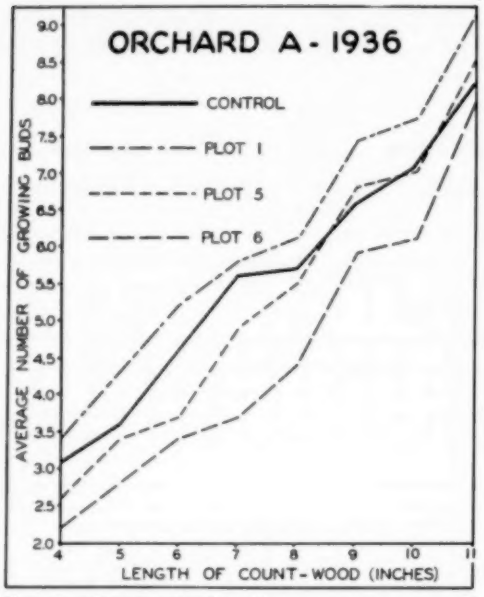

FIG. 2.—Graph showing the average number of growing buds on each length of count-wood on plots 1, 5 and 6 and the unsprayed control, Orchard A, 1936.

The average number of buds on each length of count-wood which grew during the current season is then calculated by adding each column and dividing this total by the number of counts made for each length. For example, 50 units of count-wood were examined in each length class for the results reported here, so that this number was the divisor in all cases. Next a simple graph is drawn with the classes of count-wood (lengths) on the abscissa and the average numbers of growing buds on the ordinate, as in fig. 2. The unsprayed control data are plotted on this graph, along with those of one or more plots which are to be compared with it. The consistency with which the sprayed plots differ from the control gives a general idea of the importance of the variability.

When a sprayed plot shows a variation from the control it is desirable to test the significance of the difference by statistical devices. This is rather simply done. A table is set up in which the average number of growing buds on each length for both the sprayed and unsprayed plots is listed. The differences between the respective values found for the eight count-lengths are determined (by subtraction) and recorded in a fourth column. The squares of these differences occupy column five. The two columns containing the differences and the squares of differences are then totaled, so as to give the sum of the differences and the sum of the differences squared, respectively. (See table 2.) The next step is to determine whether or not the mean difference found is significantly different from zero.

The method employed for this purpose is a standard statistical procedure which is described by R. A. Fisher in his book, *Statistical Methods for Research Workers*, Section 24—particularly his example 19. The testing criterion used is the value of t obtained, where t is the deviation of the mean difference divided by the estimated standard deviation of the mean difference. This procedure is valid mathematically on the assumption that the differences are not correlated with the length of count-wood. This assumption seems sound on the basis of data examined. Under this hypothesis the mean difference is an efficient estimate of treatment difference. Hence we test whether or not the observed value (mean variation from the control) differs significantly from zero. In order to do this, an estimate of the standard deviation of the mean difference is required. This is provided by the formula and calculation given in the example shown below. The resulting estimate has one less degree of freedom than the number of differences (number of count-lengths used) since the sum of the differences was used in its evaluation.

This method is based upon horticultural evidence that similar shoot lengths ordinarily have a comparable number of functional buds. Roberts (1926) has presented data of this nature, and our results over a five-year period appear to confirm this evidence. It seems reasonable that shoots which had made the same growth in length, even though on different trees, would be of a similar physiological type

Table 1.—Some representative data obtained by the method (average numbers of growing buds) described in this paper.

PLOT	ORCHARD	VARIETY	LENGTH OF COUNT-WOOD							
			4 inches	5 inches	6 inches	7 inches	8 inches	9 inches	10 inches	11 inches
Unsprayed	A	Wealthy	3.1	3.6	4.6	5.6	5.7	6.6	7.1	8.2
1	A	Wealthy	3.4	4.3	5.2	5.8	6.1	7.4	7.7	9.1
5	A	Wealthy	2.6	3.4	3.7	4.9	5.5	6.8	7.0	8.5
6	A	Wealthy	2.2	2.8	3.4	3.7	4.4	5.9	6.1	7.9
Unsprayed	B	Wealthy	3.4	3.9	4.2	5.2	5.3	6.8	7.3	8.2
Sprayed	B	Wealthy	3.1	3.9	4.9	5.2	6.0	7.4	8.4	9.0
Unsprayed	B	Dudley	2.7	3.5	4.2	4.6	5.6	6.0	6.8	8.4
Sprayed	B	Dudley	3.5	3.9	5.0	5.6	5.9	6.9	7.2	8.9
Unsprayed	B	Snow	2.5	2.7	3.5	3.8	4.3	5.8	7.1	7.9
Sprayed	B	Snow	2.5	3.1	4.4	4.9	5.9	6.4	6.6	8.6
Unsprayed (?)	B	McIntosh	2.4	2.7	3.1	4.1	4.4	5.3	5.7	6.8
Sprayed	B	McIntosh	2.0	2.8	3.8	4.4	4.4	5.2	5.8	7.0

and thus comparable for studying spray injury. Such inherent errors as are due to the variability of trees of the same variety, age, bearing habit and cultural condition were largely eliminated by taking data only from trees of comparable vigor. Fifteen to 20 trees were usually required in each plot to supply sufficient count-wood. Furthermore, counts have been made on opposite halves of trees which had been sprayed on one side but not the other. In all cases these results were consistent with experiments in which whole trees were used.

RESULTS OBTAINED.—The application and utility of this method are best illustrated by including sample data and calculations and presenting some of the results obtained. Table 1 gives some representative data and fig. 2 is a graphic presentation of the figures from Orchard A. The curve for plot 1 falls entirely above, and that for plot 6 falls entirely below, the curve representing the unsprayed control, whereas plot 5 gives a curve with six points below and two above the control curve. Plot 1 was sprayed with a proprietary cold mixed oil emulsion at 4 per cent; the unexpected result obtained will be discussed later. Plots 5 and 6 were sprayed with the same oil at 4 per cent, but here it was supplemented with an oil-soluble toxicant in concentrations of 1 per cent and 2 per cent respectively.

The significance of the variation between plot 5 and the unsprayed control is now determined by referring to a table of t values (Table IV of Fisher's book, for example). According to this table the 5 per cent level of significance (i.e., the t value which would be equaled or ex-

Table 2.—Data and calculations for comparing the unsprayed control and plot 5, Orchard A, 1936.

LENGTH	AVERAGE NO. GROWING BUDS IN CONTROL (x)	AVERAGE NO. GROWING BUDS IN PLOT 5 (y)	DIFFERENCE $[(y-x)=d]$	SQUARE OF DIFFERENCE (d^2)
4 inches	3.1	2.6	−.5	.25
5 inches	3.6	3.4	−.2	.04
6 inches	4.6	3.7	−.9	.81
7 inches	5.6	4.9	−.7	.49
8 inches	5.7	5.5	−.2	.04
9 inches	6.6	6.8	+.2	.04
10 inches	7.1	7.0	−.1	.01
11 inches	8.2	8.5	+.3	.09
			−2.1 (Σd)	1.77 (Σd^2)

Calculations:

Average difference $= \overline{d} = \frac{-2.1}{8} = -.26$

Formula for estimate of standard deviation of average difference: S.D. $= \sqrt{\frac{\Sigma d^2 - (\Sigma d)^2/N}{(N-1)(N)}}$

Substituting:

S.D. $= \sqrt{\frac{1.77-(2.1)^2/8}{(7)(8)}} = \sqrt{\frac{1.2187}{56}} = \sqrt{.02176} = .148$

$t = \frac{\overline{d}-o}{\text{S.D.}} = \frac{-.26}{.148} = -1.76$

Degrees of freedom $= 8-1 = 7$

Values from Fisher's Table of t (d. f. $=7$):

5 per cent level of significance $= 2.365$

1 per cent level of significance $= 3.499$

ceeded from chance alone one time in 20) is 2.365, whereas the 1 per cent level has a *t* value of 3.499. Since the *t* value calculated in this example is only −1.76, the variation between these two plots is not statistically significant. (The sign of *t* is ignored.) Plot 6 gave a *t* value of −6.05 when tested by the same procedure. Hence its deviation from the control is highly significant. Treatments 5 and 6 were used in the same block but on different trees in 1937. The *t* values obtained were −1.04 and −7.05, respectively. This gives an indication of the consistency of results obtained by this method.

A word of explanation is necessary at this point. The winter of 1935–36 was very severe in Wisconsin and an early spring survey revealed the presence of extensive cold injury to dormant fruit buds and the cambial region of one-year-old shoots. Because we had no background of experience with this type of injury, it seemed best to discourage the extensive application of dormant oil sprays in order to avoid possible additional damage. This was done, but some experimental and commercial applications were made. One experimental series consisted of a proprietary cold-mix oil used at 4 per cent, both alone and supplemented with various toxicants. The data for Orchard A were taken from this series. A grower used a proprietary mayonnaise-type emulsion at about a 6.7 per cent concentration 5.5 per cent of actual oil) on four standard varieties in a single block, leaving adjacent trees or half-trees of each variety as unsprayed controls. Counts are included from both sprayed and unsprayed trees or half-trees of each variety (Orchard B).

It has been pointed out that plot 1 (1936), in which the 4 per cent oil emulsion was used alone, appeared to be materially superior to the unsprayed control. A *t* value of 6.51 was obtained for this plot; therefore the difference is statistically significant. This result seemed unusual, but it received some striking confirmation from results obtained in near-by Orchard B. This grower had sprayed some of his trees and left the balance unsprayed, in order to prevent possible excessive damage. His observations in early summer led him to believe that the sprayed trees were superior to those left unsprayed. Counts were made to check this point and the results are included in table 1. The *t* values obtained for Wealthy, Dudley and Snow were 2.61, 6.76 and 2.61 respectively, showing that all were significantly superior to the check trees or half-trees in bud development and growth. On the other hand, the sprayed McIntosh trees quite closely duplicated the supposedly unsprayed trees of this variety (*t* value = 1.004). This discrepancy was explained by the grower a little later. It developed that he had been in error when first stating which McIntosh trees had been left unsprayed, and that practically all of the counts for this variety were made on sprayed trees!

It appears that some dormant oil treatments applied following the particular winter injuries described previously, and made under the conditions existing in the early part of the 1936 growing season, actually stimulated bud development and growth. Although a little surprising, these results are not at all unreasonable. Various writers have reported tree stimulation by dormant oil treatments under some conditions. Black (1936) in particular has reported that certain applications had a marked effect on leaf buds, causing fewer buds to remain dormant and resulting in the formation of more spurs and shoots. The main point here is that this method is just as well adapted to recording such beneficial effects as it is to measuring oil injuries. Also, two sprayed plots can be compared and the significance of the variability found can be tested statistically.

The general trend of the results obtained by this method under the conditions existing in Door County, Wis., over a period of five years, is briefly as follows:

1. A few combinations were definitely injurious. These were mainly the less refined oils used in cold-mix emulsions in concentrations of 6 per cent or higher, and similar oils used in lower concentrations but supplemented with certain toxicants.

2. Most of the treatments, including both proprietary and experimental combinations failed to show significant variations from the unsprayed controls when used according to recommendations.

3. In one year out of five (1936) certain treatments resulted in significantly superior bud development, following an unusual type of winter injury.

SUMMARY.—A method is described

which is designed to measure dormant oil effects on apple trees, and which has been successfully used in Wisconsin over a period of five years. It has the advantages of being quantitative, reasonably rapid and simple; and differences are readily subject to statistical analysis to determine their significance. It is equally well adapted to measuring both beneficial and injurious effects; results obtained with it over the period indicated have shown a consistent trend. A ruler and clip board are the only equipment required, and the counts can be made at any time after trees are in full foliage. It is not applicable to poorly-pruned old trees where little growth is being made. Bradford (1936) has suggested the substitution of weight approximations for length measurements in problems of this kind; this technique might be an additional refinement in the method. Another investigator has made the suggestion that it might sometimes be desirable to count the total number of buds present, as well as those that grew, and to classify the count-wood according to the total number of buds present, rather than by length.—1-7-38.

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Coal Tar Distillates in Dormant and Delayed Dormant Sprays on Apple Trees

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In 1926, the senior author made a search for cheap chemicals which could be efficiently used when combined with petroleum oil (employed against scale and European red mite) to control apple aphids in the delayed dormant stage of the tree, thereby replacing the highly expensive nicotine. In New Jersey the following three species of aphids, overwintering in the egg stage, are of economic importance on apples: oat aphid, *Rhopalosiphum prunifoliae* (Fitch), apple aphid, *Aphis pomi* De G., and rosy aphid, *A. rosea* (Baker).

Previous to 1926, nicotine sulfate, 1–500, was practically the only standard insecticide recommended against these aphids; it was used in combination with either petroleum oil emulsion as a delayed dormant spray or with lime sulfur as a prepink spray. Experiments at the New Jersey Agricultural Experiment Station

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during 1926, 1927 and 1928 have shown that certain coal tar derivatives, primarily of the acid group, such as cresols, xylenols and other high boiling tar acids, are toxic to aphid eggs, especially when applied at that stage of embryonic development when the outer egg layer has split, or just prior to hatching. The final results, published by Headlee & Ginsburg (1929), have established a new delayed dormant spray for apples, consisting of 3 per cent petroleum oil and 0.5 per cent crude cresylic acid. This combination is considerably cheaper than the nicotine spray. Since its introduction it has been used widely in New Jersey and in other states as a combined spray to control aphids, scale and European red mite.

It should be noted here that these results have fully corroborated the findings of Dr. A. Peterson (1918), in his experiments conducted during 1916–18, that phenols and cresols possess high toxicity to aphid eggs. The writers feel that his publication, "Some Studies on the Eggs of Important Apple Plant Lice," deserves special mention. It is an outstanding piece of work for its thoroughness, both in biological observations and insecticidal studies, and led to subsequent experiments with tar oil distillates by other investigators.

OBJECT OF THE INVESTIGATION.—Although the New Jersey apple growers hailed this new spray as a cheap substitute for nicotine, the writers as well as Dr. T. J. Headlee realized that the delayed dormant stage of the apple tree in New Jersey, designated as "the period beginning when the fruit buds show silver bands along edges of the bud scales and ending when the first leaves stick out like tiny squirrel ears," is comparatively short, varying of course, with different varieties. During normal seasons it usually ranges from 10 to 15 days, depending on temperature and other climatic factors, or from the last days in March to the middle of April.

Under adverse weather conditions such as high winds, excessive rainfall or sudden rise in temperature, many growers are unable to complete spraying of the entire orchard before the buds and leaves have advanced to a stage when injury is apt to result. It was felt that a dormant spray to replace or to supplement the delayed dormant spray should be of material aid to the apple grower. A spray which could be effectively applied between late fall and early spring should provide the farmer with unlimited opportunities for spraying his orchard. Should he, in spite of this wide latitude of time, fail to apply the dormant spray, he might still resort to the delayed dormant spray. A series of laboratory and field experiments were, therefore, started in 1933 with the purpose of perfecting a dormant apple spray suitable to New Jersey conditions.

PREVIOUS STUDIES.—While the experiments with cresylic acid against aphids were going on at the New Jersey Station, other investigators in Europe and in this country were testing the toxicity of various coal tar derivatives as a dormant spray against capsid bug, bud moth, scale, aphids and other overwintering insects. Among the European investigators Petherbridge & Weston (1926) found that commercial tar distillate preparations give practically complete control of curly plum aphids and rosy apple aphids, but no reduction was noticed of the red spider, *Oligonychus ulmi*.

Tutin (1927) conducted extensive experiments with different coal tar distillates and concluded in general that the neutral fractions are more toxic to aphid eggs than are the acid fractions, and that the high boiling neutral fractions (280–360 degrees C.) are more effective than the low boiling neutral fractions (190–280 degrees C.) against *A. pomi*. Staniland, Tutin, & Walton (1930) concluded that the destruction of eggs of the capsid bug appears to depend chiefly on smothering by the oily covering which they receive. A definite toxication possessed by tar distillates seems to be the chief factor in the destruction of eggs of apple aphid and psylla. Martin (1935) summarized the results obtained by the various investigators on this problem and discussed the preparation of combined petroleum and tar oil emulsions for dormant spraying.

Among the American investigators, Hough (1932, 1933, 1935, 1937) reported good control of scurfy and San José scales as well as apple aphids with either tar oil alone or in combination with petroleum oil applied as dormant sprays.

Elaborate experiments were carried out during the past 10 years at the New York Agricultural Experiment Station by Dr. F. Z. Hartzell and associates with emul-

sions of neutral coal tar distillates, of European and American origin, to control scale, bud moth and aphids in the dormant stage. The outstanding results are described in a series of publications by Hartzell & Parrott (1933); Hartzell (1933); Hartzell & Pearce (1934); Hartzell, Harman & Reed (1935); Hartzell (1936); Hartzell & Moore (1937).

On the whole, these investigations brought out the following information. From 1.8 to 2.4 per cent tar oil will kill eggs of apple aphids, whereas from 4 to 5 per cent are necessary to control San José, scurfy and oystershell scales. However, since the scale as well as the European red mite are readily controlled with petroleum oil, which costs approximately half as much as the tar oil, a combined dormant spray consisting of about 2.5 per cent tar oil and 3 per cent petroleum oil is efficient in controlling all these insects.

No tree injury resulted from this dormant spray, if applied before the fruit buds began to swell. Apparently the maximum concentration of oil, either as tar distillate alone or combined with petroleum oils, which the dormant apple tree can stand is about 6 per cent. Higher oil concentrations are apt to cause retardation in bud development. It further appears that tar oils of American origin are as effective as the more expensive miscible and emulsified products from England and other European countries.

COAL TAR DISTILLATES.—Coal tar is obtained by destructive distillation of coal, in the manufacture of either coke or illuminating gas. It is a complex mixture of hydrocarbons generally classified as (1) acidic, (2) basic and (3) neutral. The acid compounds include phenols, cresols, xylenols and other high boiling acids. The basic group consists chiefly of pyridine and quinoline compounds. The neutral group contains hydrocarbons of the aromatic series; namely, benzene and its homologues, naphthalene and anthracene. The crude tar may be used as such for some industrial purposes or is further fractionated by distillation into the following distillates: (1) light oil—80–170 degrees C.; (2) middle or carbolic oil—170–240 degrees C.; (3) heavy or creosote oil—240–270 degrees C.; (4) green or anthracene oil—270–400 degrees C.

The neutral tar distillates, used for insecticidal purposes, are obtained from the creosote and anthracene fractions. The term creosote, however, is generally applied to tar distillates heavier than water, coming over above 200 degrees C.

METHODS AND MATERIALS.—All the experiments here reported were conducted in two commercial orchards located in Marlton and Glassboro, N. J. Blocks of several varieties of apple trees (8 to 12 per block) infested with eggs of aphid and European red mite were sprayed with dormant and delayed dormant sprays during four successive seasons, from 1934 to 1937, inclusive. Spraying was done with a Bean power sprayer. Checks, or unsprayed blocks of each variety, were left for comparison. After the observations were completed the check blocks were sprayed at the prepink or pink stage with lime sulfur and nicotine. The insecticides tested consisted of various concentrations of coal tar oil, combinations of tar and petroleum oils, and petroleum oil mixed with different proportions of cresylic acid. Both commercial and laboratory prepared emulsions of the oils were used. The coal tar oil was essentially a high boiling neutral fraction containing 5 per cent tar acids, 2 per cent coke and 3 per cent water. The petroleum oil was a paraffin, light lubricating distillate of the following specifications: Bé gravity, 26–28; viscosity (Saybolt/100 degrees F.), 110; boiling range, 650–770 degrees F.

Observations on insects were made prior to the prepink spray, with the exception of rosy aphids which were in some experiments also examined after the prepink spray. On aphids, a minimum of 100 buds or more in each variety of each treatment was examined and the per cent buds free from live aphids recorded. For European red mite, 100 leaves or more in each variety of each block were examined under a magnifying glass and the total number of live mites noted. Usually the counts in each series of treatments, including the check blocks, were made on the same day. The results are reported separately for each year. The following varieties of apple trees were used: Delicious, Stayman, Wealthy, Rome, Winter Banana, Starr and Henry Clay.

EXPERIMENTS IN 1934.—Delicious apple trees in the Marlton Orchard infested with eggs of European red mite and aphids were selected for the tests. Two commercial emulsions of tar oil were used.

The sprays were applied on March 29, when the buds were still dormant. One block of 12 trees was sprayed with an emulsion containing 83 per cent straight tar, 6 gallons of the stock being used to 94 gallons of water. This made approximately 5 per cent of actual tar oil in the diluted spray. Another block of the same number of trees was sprayed with an emulsion containing 50 per cent tar oil and 33 per cent petroleum oil; again 6 gallons of stock was mixed with 94 gallons of water. The diluted spray contained 3 per cent petroleum oil and about 2 per cent tar oil. A third block was left unsprayed and served as a check. About 200 fruit spurs from each block were examined for aphids on the following dates: April 12, 23 and May 11. No live aphids were found in the two treated blocks, but abundance of live oat and apple or green aphids were present in the check blocks. No injury whatsoever resulted either to the buds or the subsequent development of foliage. The bark on the sprayed trees had a yellowish to brown appearance. This color was decidedly more pronounced in the block treated with 5 per cent tar oil than on the trees sprayed with the mixture of tar and petroleum oils.

EXPERIMENTS IN 1935.—During this season four different dormant sprays were tested, in comparison with the delayed dormant spray, on three varieties of apple trees. One series of sprays was run on seven blocks in the Marlton Orchard. A block consisted of two rows and contained from six to eight trees of each of the following varieties: Stayman, Wealthy and Rome, or a total of from 18 to 24 trees. The dormant sprays were applied on March 20 and the delayed dormant during the first week in April. Observations on aphids were made on April 15. The composition of the spray mixtures and the results obtained are given in table 1.

Table 1.—Effect of dormant sprays on all kinds of apple aphids, on three varieties of trees, in Marlton Orchard, 1935.

Number of Spray Mixture	Time and Composition of Spray	Stayman		Wealthy		Rome		Average Per Cent Buds in All Varieties Free from Live Aphids
		Buds Examined	Per Cent Buds Free from Live Aphids	Buds Examined	Per Cent Buds Free from Live Aphids	Buds Examined	Per Cent Buds Free from Live Aphids	
1	Check (no oil spray)	180	60.0	240	76.3	240	67.1	67.8
2	Dormant: Petroleum oil, 4% Cresylic acid, 0.5%	180	97.2	240	95.0	240	88.0	93.4
3	Dormant: Petroleum oil, 4% Cresylic acid, 1%	180	97.8	240	95.5	240	94.6	96.0
4	Dormant: Petroleum oil, 5% Cresylic acid, 0.5%	180	96.1	210	97.6	210	97.6	97.1
5	Dormant: Petroleum oil, 3% Tar oil, 2.4%	180	99.1	240	99.6	210	98.8	99.2
6	Delayed Dormant: Petroleum oil, 3% Cresylic acid, 0.5%	180	90.0	240	97.5	180	95.0	94.2
7	Delayed Dormant: Petroleum oil, 3% Cresylic acid, 0.5% (Laboratory prepared emulsion)	120	100.0	120	100.0	90	97.8	99.2

The observations on aphids disclose

that the cresylic acid plus petroleum oil sprays gave from 93.4 to 97.1 per cent control; the tar oil spray averaged 99.2 per cent control for the three varieties, and the delayed dormant spray produced from 94.2 to 99.2 per cent control. The control of European red mite was practically 100 per cent since no live mites could be found in any one of the sprayed blocks. On the other hand, the unsprayed blocks showed abundance of both aphids and mites. Most of the live aphids were of the oat and apple species; very few rosy aphids were found.

A second series of tests with identically the same spray mixtures was run simultaneously in the Glassboro Orchard on the Rome variety. The dormant sprays were applied on March 16 and the delayed dormant on March 27. Observations for live aphids were made on April 16 and again on April 23. The results are given in table 2. In this orchard, as in the other, the aphids were mainly of the oat and apple or green species.

A comparison of the results from the two series of experiments indicates that of the dormant sprays either a mixture containing 3 per cent petroleum oil and 2.4 per cent tar oil or one containing 4 per cent petroleum oil and from 0.5 to 1 per cent cresylic acid gave control of aphids comparable to that obtained by the delayed dormant spray. Since, however, only oat and green aphids in large numbers were encountered, whereas rosy aphids are of greater economic importance, it was felt that the results obtained during this year are not conclusive for spray recommendations. No tree injury from any one of the dormant sprays was observed.

EXPERIMENTS IN 1936.—The tests carried out in 1935 were repeated in 1936 on the same three varieties of trees in the Marlton Orchard. The dormant sprays were applied on March 16 and the delayed dormant on March 31. Counts of live aphids were made on April 7, 9, 15 and 21. The aphid infestation was heavy on Stayman and Rome but very light on Wealthy. For this reason observations on Wealthy were not made. All three species of apple aphids were present this season, although the rosy was only about 15 per cent of the total. A summary of all the counts, presented in table 3, demonstrates that the dormant spray number 5, consisting of 3 per cent petroleum oil and 2.4 per cent tar oil, gave the highest control, averaging 97.6 per cent aphid-free buds. Spray 6, the delayed dormant, was a close second with 97.4 per cent. The other three dormant sprays proved less effective.

On May 21 the Rome blocks and on June 9 the Stayman blocks were again examined exclusively for rosy aphids. The

Table 2.—Effect of dormant sprays on all kinds of apple aphids on Rome in Glassboro Orchard, 1935.

Number of Spray Mixtures	Composition of Spray	Time of Application	Examined April 16		Examined April 23	
			Buds Examined	Per Cent Buds Free from Live Aphids	Buds Examined	Per Cent Buds Free from Live Aphids
1	Check (no oil spray)		500	30.0	100	43.0
2	Petroleum oil, 4% Cresylic acid, 0.5%	Dormant	400	99.3	150	100.0
3	Petroleum oil, 4% Cresylic acid, 1%	Dormant		99.8	125	98.5
4	Petroleum oil, 5% Cresylic Acid, 0.5%	Dormant		99.0	150	99.4
5	Petroleum oil, 3% Tar oil, 2.4%	Dormant	400	99.3	125	100.0
6	Petroleum oil, 3% Cresylic acid, 0.5%	Delayed Dormant	400	95.0	125	99.2

Table 3.—Effect of dormant sprays on all kinds of apple aphids in Marlton Orchard, 1936.*

Number of Spray Mixture	Composition of Spray	Time of Application	Stayman		Rome		Average Per Cent Buds Free from Live Aphids in Both Varieties
			Buds Examined	Per Cent Buds Free from Live Aphids	Buds Examined	Per Cent Buds Free from Live Aphids	
1	Check (no oil spray)	—	500	8.5	700	23.0	15.7
2	Petroleum oil, 4% Cresylic acid, 0.5%	Dormant	200	79.0	500	85.5	82.3
3	Petroleum oil, 4% Cresylic acid, 1%	Dormant	500	92.8	600	93.7	93.2
4	Petroleum oil, 5% Cresylic acid, 0.5%	Dormant	500	96.2	600	93.4	94.8
5	Petroleum oil, 3% Tar oil, 2.4%	Dormant	500	97.0	600	98.2	97.6
6	Petroleum oil, 3% Cresylic acid, 0.5%	Delayed Dormant	200	98.5	500	96.2	97.4

* The number of live aphids per infested bud ranged from 1 to 3 in the sprayed blocks and from 4 to 10 in the checks.

results, presented in table 4, show 100 per cent control from sprays 5 and 6 and about 78 to 91 per cent control from the other dormant sprays.

Table 4.—Effect of dormant spray on rosy aphids in the Marlton Orchard 1936; 100 fruit spurs of each variety, in each block, were examined.

Number of Spray Mixture	Time and Composition of Spray	Stayman	Rome	Per Cent Spurs Free from Live Aphids in Both Varieties
		Per Cent Spurs Free from Live Aphids	Per Cent Spurs Free from Live Aphids	
1	Check (no oil spray)	91	80	85.5
2	Dormant: Petroleum oil, 4% Cresylic acid, 0.5%	82	85	84.5
3	Dormant: Petroleum oil, 4% Cresylic acid, 1%	78	84	81.0
4	Dormant: Petroleum oil, 5% Cresylic acid, 0.5%	85	83	84.0
5	Dormant: Petroleum oil, 3% Tar oil, 2.4%	100	100	100.0
6	Delayed Dormant: Petroleum oil, 3% Cresylic acid, 0.5%	100	100	100.0

RED MITE.—A check-up on the European red mite, *Paratetranychus pilosus* (C. & F.), was made on May 5 in Stayman and Wealthy varieties. The results, in table 5, show good control in all the sprayed blocks, ranging from 0 to 4 live mites per 100 leaves, whereas the check blocks had 50 and 126 live mites on the same number of leaves in the Wealthy and Stayman varieties, respectively.

Table 5.—Effect of dormant sprays on European red mite in the Marlton orchard, 1936.

Number of Spray Mixture	Time and Composition of Spray	Stayman	Wealthy
		Live Mites on 100 Leaves	Live Mites on 100 Leaves
1	Check (no oil spray)	126	50
2	Dormant: Petroleum oil, 4% Cresylic acid, 0.5%	3	1
3	Dormant: Petroleum oil, 4% Cresylic acid, 1%	3	4
	Dormant: Petroleum oil, 5% Cresylic acid, 0.5%	0	0
5	Dormant: Petroleum oil, 3% Tar oil, 2.4%	0	
6	Delayed Dormant: Petroleum oil, 3% Cresylic acid, 0.5%	0	0

TREE INJURY.—No injury nor retardation to bud development could be noticed in any of the dormant sprayed blocks. Where the delayed dormant sprays were applied, appreciable injury occurred to fruit buds and early foliage of Stayman and Rome, but practically no injury was observed on Wealthy. This may be ascribed largely to a sudden rise

Table 6.—Effect of commercial and home made tar oil sprays on aphids, on three varieties of apple trees in the Glassboro Orchard, 1937; 400 fruit spurs of each variety, in each block, were examined.

Number of Spray Mixture	Composition of Spray	Time of Application	Per Cent Spurs Free from Live Aphids					
			Winter Banana		Starr		Henry Clay	
			All Aphids	Rosy Aphids Only	All Aphids	Rosy Aphids Only	All Aphids Only	Rosy Aphids
1	Check (no oil spray)	—	54.8	92.5	66.0	88.5	91.5	99.5
5	Petroleum oil, 3% Tar oil, 2.4% (homemade emulsion)	Dormant	96.3	99.8	99.0	99.8	99.5	99.8
5	Petroleum oil, 3% Tar oil, 2.4% (commercial emulsion)	Dormant	98.0	99.8	99.8	100.0	99.5	100.0

in temperature during the last week in March which forced the buds on the early varieties before the spraying was completed.

In general, the results secured during this season clearly indicate that the dormant spray of 3 per cent petroleum oil and 2.4 per cent tar oil is superior to the other dormant sprays tested; it is as efficient as the delayed dormant spray in the control of the three species of aphids and has no injurious effects on the tree.

EXPERIMENTS IN 1937.—A comparison was made between the commercial and homemade tar plus petroleum oil emulsions. Three varieties, namely, Winter Banana, Starr and Henry Clay, in blocks of about 10 trees each, located in the Glassboro Orchard were sprayed early in March, when the buds were completely dormant. The homemade stock emulsion consisted, by volume, of 37 parts petroleum oil, 30 parts tar oil, 33 parts water and 1 part, by weight, of *Goulac* (sulphite lignin pitch) emulsifier. Eight gallons of this emulsion mixed with 92 gallons of water gave the desired 3 per cent petroleum oil and 2.4 per cent tar oil. On April 28 and 29, shortly after leaves had formed, counts were made of buds showing all kinds of aphids and of fruit spurs showing rosy aphids. For this purpose, 400 spurs of each variety in each block were examined. The results, presented in table 6, show no appreciable differences between the two emulsions. In each case good control was secured with no noticeable injury to buds or foliage.

SUMMARY AND CONCLUSIONS.—Experiments were conducted with dormant and delayed dormant sprays to control aphids and European red mite on several varieties of apple trees. The dormant sprays consisted of emulsified neutral tar oils; emulsified petroleum and tar oils combined; and emulsified petroleum oil to which various concentrations of cresylic acid were added. The delayed dormant spray consisted of emulsified petroleum oil and 0.5 per cent cresylic acid. The results obtained during the past four years in two commercial orchards suggest the following conclusions.

Of the various dormant sprays tested, an emulsion containing 3 per cent petroleum oil and about 2.5 per cent neutral tar oil is equal in efficiency to the present New Jersey delayed dormant spray in controlling apple aphids and European red mite. It causes no noticeable injury or retardation to the buds. The dormant spray has an advantage over the delayed dormant spray in that it can be applied over a longer period of time. It has a disadvantage in that its present cost is considerably higher.—1-7-38.

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Evaluating Derris and Cubé: The Question of Total Extractive Content

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It is generally agreed by investigators working with derris and cubé that both rotenone and total extractive content must be considered in the insecticidal evaluation of these roots, and several suggestions have been made for using the two quantities jointly in evaluating toxicity (Hoyer & Leonard 1936; Jones & Smith 1936).

There is, however, considerable variation in the solvents and methods used by different laboratories for the determination of the total extractive content. Ether is widely used both in this country and abroad, but with variations in the time of extraction. Carbon tetrachloride, benzene and, more recently, chloroform have been used in this and other laboratories. It is desirable to use a solvent that extracts all the toxic material, but as little nontoxic material as possible, so that the most nearly correct assessment of content of active material will be obtained. Therefore the writers studied this question with a view to selecting the best solvent and method for the determination.

DETERMINING TOTAL EXTRACTIVE CONTENT.—The methods of extraction tested included Soxhlet extraction for various periods, with several solvents, and both single extraction followed by aliquoting and multiple extraction at room temperature with chloroform. The two last methods have been described in connection with the determination of rotenone (Jones & Graham 1938). Five-gram samples were used in all cases except in the aliquot method, in which larger samples were used but aliquots of the extracts taken equivalent to a 5-g. sample. The amount of total extractive material was determined by drying the evaporated extract for 24 hours at 105 degrees C. In all cases except in the aliquot method, tests for completeness of extraction of the rotenone were made on the marcs by extracting them with acetone and testing the acetone extract by the modified Dur-

ham color test as described in a previous work (Jones & Graham 1938). The results of this color test have been shown to be well correlated with toxicity to insects (Jones, Campbell & Sullivan 1935).

The results of these extractions are shown in table 1. On examining first the percentages of extractives obtained with various solvents, it is seen that in the seven-hour Soxhlet extraction the percentage of material extracted by carbon tetrachloride and ether was in general lower than that by most other solvents. Benzene also gave lower values in some cases. Values for chloroform, ethylene dichloride, trichloroethylene and ethyl acetate were of about equal magnitude. Acetone generally extracted more material than these, and methyl alcohol considerably more. When a sample of each root was extracted for an extended length of time with ether or benzene, the amount of material removed agreed with that extracted by chloroform and other solvents. It has already been shown by other investigators (Koolhaas & Meijer 1937) that exhaustive extractions with ether and benzene give about the same values.

From the tests of the marcs it is immediately seen that, in general, extraction of the rotenone by carbon tetrachloride and ether was far from complete in seven hours. Of the solvents giving about the same amount of total extractives, chloroform was the only one that gave complete extraction from all samples. Acetone and methyl alcohol also gave practically complete extraction of the samples tested. Of those solvents that gave satisfactorily complete extraction of the rotenone, chloroform gave the lowest total extractive content. From the standpoint of amount of total extractives as well as ease and completeness of extraction of rotenone, chloroform thus appears to be the most suitable solvent.

Although results with chloroform at room temperature by the multiple-extraction procedure were on the average higher, and those by the aliquot procedure slightly lower, they were in general in accord with those by Soxhlet extraction.

TOXICITY DETERMINATION.—To determine whether some toxic material not shown by the Durham color test remained in the roots after extraction, the marcs of three samples each of derris and cubé were tested against mosquito larvae.

The marcs from the seven-hour chloroform extraction were allowed to dry at room temperature and were then extracted for seven hours in a Soxhlet with acetone. The marcs from this extraction were again dried and similarly extracted with methyl alcohol. Finally, the dried marcs from the alcohol extraction were soaked in hot water for several days. Similar extracts were prepared of the marcs from the chloroform, room-temperature, multiple-extractions of one sample of derris and one of cubé root. Acetone extracts were also made of the marcs from Soxhlet extractions with benzene and ether for seven hours and for longer periods and with chloroform for a longer period, in each case on one sample of derris and one of cubé.

These acetone, methyl alcohol and water extracts of the marcs were concentrated, and each was made to a volume of exactly 10 cc. Since the original sample of root weighed 5 g., 1 cc. of these extracts was equivalent to 500 mg. of plant material. This was the maximum concentration obtainable without causing undue separation of solid matter from the extracts. These extracts were then tested against mosquito larvae by the method of Campbell, Sullivan & Smith (1933) in a concentration of 0.2 cc. per 100 cc., equivalent to 1000 parts of the original root per million parts water. Rotenone, 1 part per million, was used as a standard.

The results are shown in table 2. Where the term "nontoxic" is used, the mortalities were so low as to be insignificantly different from the checks. It will be noted that the average mortality from rotenone is approximately 50 per cent. Thus, at the concentrations used, if an extract contained any material as toxic as rotenone to an amount equivalent to 0.1 per cent of the root, a 50 per cent mortality would be expected. It will be noted that marcs from the seven-hour chloroform extracts were nontoxic, except in the case of two derris samples. These two samples have a comparatively high ratio of rotenone to total extract, which has been shown in a previous work (Jones & Graham 1938) to make complete extraction of the rotenone more difficult. Even the methyl alcohol extracts from one of these was slightly toxic. All other methyl alcohol extracts and all water extracts in this series were nontoxic. Acetone extracts of

Table 1.—Total extractive content of several samples of derris and cubé roots by various extraction procedures.

Original Method and Solvent	Derris Roots										Cubé Roots									
	3001 (5.4)[1]		3002 (2.0)[1]		3006 (3.6)[1]		3126 (5.8)[1]		3307 (7.4)[1]		3004 (2.9)[1]		3005 (5.6)[1]		3230 (3.9)[1]		3260 (4.4)[1]		3596 (3.8)[1]	
	Total Extractives, Per Cent	Marc[2]	Total Extractives, Per Cent	Marc[2]	Total Extractives, Per Cent	Marc[2]	Total Extractives, Per Cent	Marc[2]	Total Extractives, Per Cent	Marc[2]	Total Extractives, Per Cent	Marc[2]	Total Extractives, Per Cent	Marc[2]	Total Extractives, Per Cent	Marc[2]	Total Extractives, Per Cent	Marc[2]	Total Extractives, Per Cent	Marc[2]
Seven-Hour Soxhlet:																				
Chloroform	15.5	0	12.3	0	16.2	0	16.1	0	19.6	0	16.2	0	18.2	0	19.1	0	20.7	0	18.6	0
Benzene	14.8	1			15.8	0	15.9	1	19.2	2	16.2	0	17.6	0	18.7	0	20.4	0		
Ether	14.8	3			15.4	2			18.8	3	16.1	1	17.7				18.5	3		
Carbon tetrachloride	14.2	3			15.2	3	15.2	3	18.8	3	15.9	2	17.4	0	18.5	0	20.2	1		
Ethylene dichloride	15.6	0			16.1	0	16.4	0	19.6	1	16.4	0	18.4	0	19.2	0	20.6	0		
Trichloroethylene	15.4	0			16.2	0	16.1	0	19.4	2	16.5	0	17.9	0	18.9	0	20.9	0		
Ethyl acetate	15.6	1			16.5	0	16.4	1	19.8	2	16.6	0	18.2	0	19.1	0	20.6	0		
Acetone							17.5	1	20.5	1					20.0	0	20.6	0		
Methyl alcohol							23.1	0	24.1	0					26.4	0	25.4	0		
Prolonged Soxhlet:																				
Chloroform (28 hrs.)	15.6	0							19.6	0										
Benzene (44 hrs.)									19.7	0										
Ether (cubé, 49 hrs.; derris, 70 hrs.)									19.9	1			18.2	0						
Room-temperature, multiple-extraction:																				
Chloroform							16.5	1	19.7	2			18.6	1			21.0	1		
Room-temperature, aliquot:																				
Chloroform	15.3		11.8		16.0		16.2		19.9		16.1		18.5		18.8		20.6		18.0	

[1] Numbers in parentheses following sample numbers indicate per cent of rotenone as determined by the chloroform, room-temperature, aliquot method (Jones & Graham 1938).
[2] 0, negative; 1, fairly positive; 2, medium positive; 3, strongly and very strongly positive, according to Durham color test.

Table 2.—Additional extractive content and mortality to mosquito larvae of marcs of derris and cubé roots from various extraction procedures.

Original Method and Solvent	Solvent Used for Extraction of Marc	Derris Roots						Cubé Roots					
		3001(.35)[1]		3006(.22)[1]		3307(.37)[1]		3004(.18)[1]		3005(.30)[1]		3260(.21)[1]	
		Additional Extractives, Per Cent	Mortality, Per Cent	Additional Extractives, Per Cent	Mortality, Per Cent	Additional Extractives, Per Cent	Mortality, Per Cent	Additional Extractives, Per Cent	Mortality, Per Cent	Additional Extractives, Per Cent	Mortality, Per Cent	Additional Extractives, Per Cent	Mortality Per Cent
Seven-hour Soxhlet:													
Chloroform	Acetone	1.9	28(70)[2]	3.7	Nontoxic	1.2	20(70)[2]	0.5	Nontoxic	0.9	Nontoxic	0.4	Nontoxic
	Methyl alcohol	6.9	Nontoxic	6.6	Nontoxic	4.4	6(70)[2]	5.8	Nontoxic	5.4	Nontoxic	4.8	Nontoxic
	Water	4.9	Nontoxic	5.7	Nontoxic	8.0	Nontoxic	7.1	Nontoxic	10.8	Nontoxic	6.8	Nontoxic
Benzene	Acetone						62(36)[2]				Nontoxic		
Ether	Acetone						100(36)[2]				98(36)[2]		
Prolonged Soxhlet:													
Chloroform (28 hrs.)	Acetone	1.6	19(36)[2]			0.7	7(36)[2]						
Benzene (44 hrs.)	Acetone						22(70)[2]						
Ether (derris, 70 hrs.; cubé, 49 hrs.)	Acetone						90(61)[2]				12(61)[2]		
Room-temperature, multiple-extraction:													
Chloroform	Acetone					1.2	53(36)[2]			0.9	Nontoxic		
	Methyl alcohol					3.7	11(36)[2]			5.3	11(36)		
	Water					6.3	Nontoxic			7.1	Nontoxic		

[1] Numbers in parentheses following sample numbers indicate the ratio of rotenone content to total extractive content by the chloroform, room temperature, aliquot method.
[2] Numbers in parentheses in body of table indicate the mortality from rotenone at one part per million when tested simultaneously by the same original procedure. The mortality from solvent checks averaged 2 per cent.

the marcs from prolonged chloroform extractions of the two derris samples showing residual toxicity after seven hours treatment were much less toxic. Thus, for all practical purposes the toxic material even in these samples may be considered completely soluble in chloroform. Room-temperature multiple-extractions with chloroform left more toxic material in the marcs than did seven-hour Soxhlet extractions.

The marc from a seven-hour benzene extraction of a cubé sample was nontoxic, but that from a derris sample was relatively toxic. Marcs from seven-hour ether extractions of both these roots were highly toxic, as might be expected from the chemical work. A longer benzene extraction of the derris root reduced the amount of toxic material left in the marc. Prolonged ether extraction reduced the toxic material in the cubé root to a low value; although it slightly reduced the toxic material in the derris sample, still left this sample highly toxic.

No test was made of the final marcs from the water extractions, because of the impracticability of obtaining sufficient concentrations of possible toxic ingredients to be significant in tests with mosquito larvae. It is unlikely, however, that any toxic material remained after extraction with the solvents used.

TOXICITY RESULTS.—In a discussion of the toxicity results, it must be kept in mind that tests were made at a comparatively high concentration; therefore, an appreciable mortality does not necessarily indicate a large amount of toxic material. Thus, marcs from the seven-hour chloroform extractions of two derris samples were appreciably toxic, while those from prolonged extraction were much less toxic. Since the amount of material removed in the prolonged extraction was insignificantly different from that in the seven-hour extraction, for the determination of total extractive content a seven-hour chloroform extraction would be entirely satisfactory.

While marcs from the chloroform, room-temperature, multiple-extraction method were definitely more toxic than those from seven-hour Soxhlet extraction, the amount of total extractives by the former method was slightly higher on the average than that by Soxhlet extraction. The fact that the chloroform, room-temperature, aliquot method gives results only slightly lower than those by seven-hour Soxhlet extraction is of particular interest because a recent study (Jones & Graham 1938) has shown this to be the most satisfactory method of extraction for use in the determination of rotenone. It would therefore be convenient and time saving to determine the total extractive content simultaneously with the rotenone content merely by taking a small additional aliquot of the filtered extract.

Although the seven-hour, chloroform-Soxhlet extraction gives a more nearly accurate indication of the total extractive content, the room-temperature, aliquot procedure gives results agreeing closely enough with these to be satisfactory for practical purposes.

The results in both tables 1 and 2 readily demonstrate the much greater ease of extraction of cubé over derris root, which has already been mentioned in a previous work (Jones & Graham 1938). This is particularly evident in comparing the results on samples 3005 and 3307 in table 2.

SUMMARY AND CONCLUSIONS.—Of several solvents tested for the determination of total extractive content of derris and cubé roots from the standpoint of selective extraction of the toxic material, chloroform was the most satisfactory. Soxhlet extractions for seven hours with this solvent gave satisfactorily complete extraction of the toxic material. Results by the room-temperature, aliquot procedure were in fair agreement with these, although on the average slightly lower. Because of the convenience of the determination, particularly when rotenone is being determined on the sample by the same method, the latter procedure is suggested as suitable for determination of total extractive content.—1-7-38.

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Effect of Addition of Oil on the Toxicity to Plant Bugs of Derris and Other Insecticides

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Certain large plant bugs, such as the squash bug, *Anasa tristis* (De G.), the harlequin bug, *Murgantia histrionica* (Hahn), and the southern green stinkbug, *Nezara viridula* (L.), have been difficult to control with known insecticides. White & Brannon (1933) concluded that derris extract was the most efficient of materials tested against the harlequin bug.

Lightbody & Mathews (1936a) have found that rotenone dissolved in olive oil is much more toxic to white rats when given orally than when given as the solid or in suspension. The same authors (1936b) also found that, when young adult white rats are fed extracts from derris or cubé root powders in olive oil solution, the toxicity is greater than would be expected on the basis of the rotenone content.

Laboratory tests were performed by the writers to determine if the toxicity of the derris powder in water to plant bugs could be increased by the use of oil emulsions. Oil emulsions were also used with acetone extract of derris, with suspensions of derris that had been covered with acetone for 24 hours, and with three other insecticides commonly used against plant bugs: free nicotine, nicotine sulfate and anabasine sulfate. A few tests were made with pyrethrum and with derris dusts.

Oils with varying drying properties were selected. Tung oil, teaseed oil and corn oil were purchased on the open market; the others were of U. S. P. quality. Oil of petrolatum (heavy) was used to represent the paraffin hydrocarbon series.

Technical sodium lauryl sulfate was used as the emulsifying agent in all the tests except those involving acetone, when triethanolamine oleate was substituted.

The derris powder used in the tests contained 4.5 per cent of rotenone and 14.5 per cent of carbon tetrachloride extractives, as determined by the Division of Insecticide Investigations of the Bureau of Entomology and Plant Quarantine.

PREPARATION OF THE EMULSIONS.—The oil emulsions with derris were prepared with the following quantities: Technical sodium lauryl sulfate, 0.1 gram (0.3 gram in some tests); water, 5 ml.; oil, 2 ml. (4 ml. for 2 per cent emulsions); derris, 0.44 gram (for spray of 0.01 per cent rotenone content); and water to make 200 ml. unless otherwise noted. The sodium lauryl sulfate and water were stirred with an electric mixer until the former was completely dissolved. The measured quantity of the oil was then slowly added and the mixture was stirred for several minutes until an emulsion was obtained. The derris was introduced and the mixture again stirred. Water was then added to obtain the desired dilution.

The derris in acetone was prepared by mixing 0.555 gram of derris with 5 ml. of acetone and allowing it to stand for 24 hours before adding the other materials.

The triethanolamine oleate used in the derris-acetone emulsions was made by stirring together equal volumes of triethanolamine and oleic acid in the mixer. It was used at the rate of 0.2 ml. to 200 mls. of the final solution.

The oil emulsions incorporating free nicotine, nicotine sulfate and anabasine sulfate were prepared by the same procedure as described for derris, and were all prepared from 40 per cent solutions.

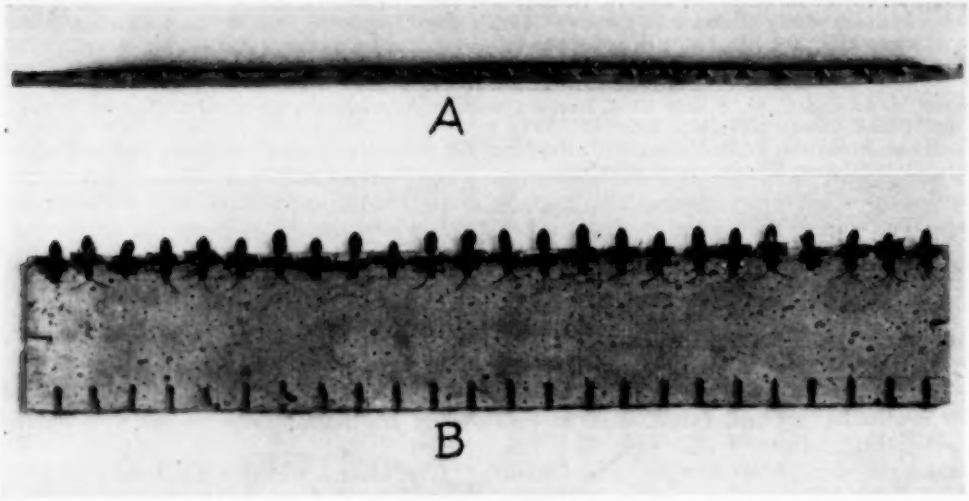

FIG. 1.—A: Side view of sheet of cork with slots cut to fit thorax of large milkweed bug. B: Top view of cork, showing bugs in place on one edge, and chilled slab below.

Since a large quantity of foam was usually present on top of the emulsion, the sample to be atomized was removed with a pipette.

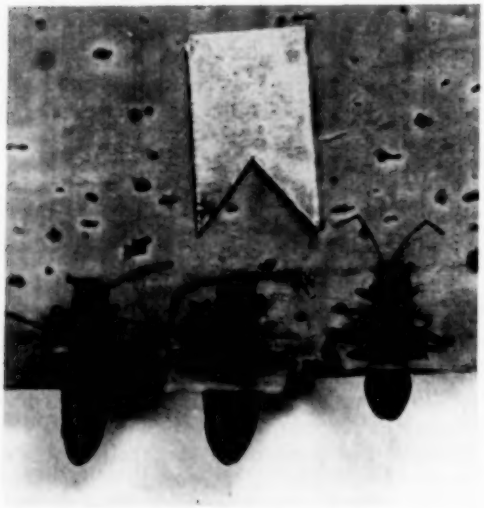

FIG. 2.—Top view of cork holder (enlarged), showing bugs and metal barrier to prevent legs from spreading insecticide placed on abdomen.

TEST INSECTS.—Since sufficient adults of the squash bug, *A. tristis*, were available during only a short period in the fall, and the large milkweed bug, *Oncopeltus fasciatus* (Dall.), can be reared easily in large numbers on milkweed seeds, the latter species was selected as a test insect for the perfection of the technique and to obtain some knowledge as to the effectiveness of known insecticides against plant bugs (Simanton & Andre 1935). When squash bugs became available in large numbers they were used in these experiments.

CAGE TESTS WITH SQUASH BUGS.—One per cent oil emulsions were used in all the tests with the squash bug. Fifty bugs were confined in a screen cylinder approximately 10 inches high and 6 inches in diameter made of 16-mesh wire cloth and placed on a revolving table. Fifteen milliliters of the insecticide were sprayed with an atomizer at a constant pressure of 10 pounds, the nozzle being raised and lowered at a uniform rate. The bugs were immediately removed to screen cages 6 by 6 inches and placed in a constant temperature cabinet, which was held at 80 degrees F. and either 40 or 70 per cent relative humidity for the duration of the test. Mortality records were taken at 24-hour intervals. No food or water was provided for the duration of the test. Some tests were discontinued after 48 hours, the majority after 72 hours.

TESTS WITH INDIVIDUAL MILKWEED BUGS.—A concentration of 0.01 per cent rotenone was used in all the tests with derris against the large milkweed bug. Both 1 and 2 per cent emulsions and two concentrations of emulsifying agent were

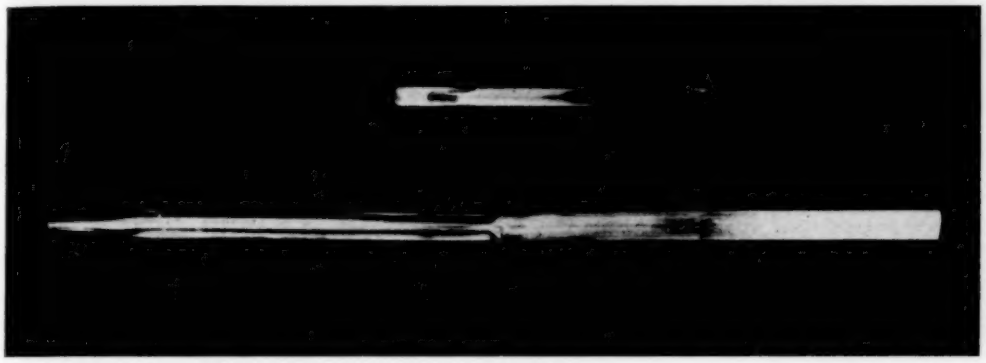

FIG. 3.—Pipette and plunger for application of a measured dose of insecticide to a single bug.

used. Individual bugs were treated with measured doses from a special pipette (Nelson *et al.* 1934). A special holder was made by cutting trapezoidal slots in sheets of cork or balsa wood, fig. 1. A bug was placed in each slot, which held the thorax, leaving the legs free and the abdomen projecting over the edge. A small metal barrier, fig. 2, prevented the bug from reaching the abdomen with its legs, and thus any loss of insecticide or contamination of any other part of the body was prevented. The wings of the bug after it was placed in the slot were moved slightly so that they would not cover the abdomen.

Before these tests were begun, an excess number of bugs was removed from the source cages and chilled for 20 minutes in the refrigerator to facilitate handling. Individuals were then removed at random from the chilled vessel and placed in the holder, barriers were adjusted and, when the holder board was filled, the unit was placed for 30 minutes in the constant temperature cabinet which was kept at 80 degrees F. and 50 per cent relative humidity.

A measured dose of insecticide was applied to the dorsal side of the abdomen of each insect by means of a pipette, fig. 3. The pipette was made by fusing a capillary tube to a thin walled glass tube and grinding a plunger to the diameter required to fit the thin walled tube. It was calibrated and found to deliver 0.0123 ml. of liquid. The dose was taken from the stock solution while the mixer was running at slow speed in order to obtain a true sample of suspended particles. The average weight of the milkweed bug was found to be 63.8 mg., and the amount of rotenone applied to each individual was 3.1 micrograms.

Immediately after treatment of the bugs, the boards with the bugs were

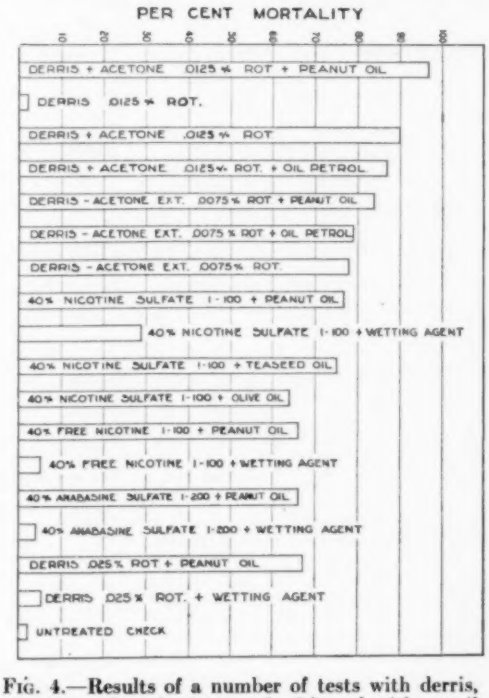
PER CENT MORTALITY
0
10
20
30
40
50
60
70
80
90
100
DERRIS + ACETONE .0125 % ROT + PEANUT OIL
DERRIS .0125 % ROT.
DERRIS + ACETONE .0125 % ROT
DERRIS + ACETONE .0125% ROT. + OIL PETROL
DERRIS - ACETONE EXT. .0075 % ROT + PEANUT OIL
DERRIS - ACETONE EXT. .0075 % ROT + OIL PETROL
DERRIS - ACETONE EXT. .0075% ROT.
40% NICOTINE SULFATE 1-100 + PEANUT OIL
40% NICOTINE SULFATE 1-100 + WETTING AGENT
40% NICOTINE SULFATE 1-100 + TEASEED OIL
40% NICOTINE SULFATE 1-100 + OLIVE OIL
40% FREE NICOTINE 1-100 + PEANUT OIL
40% FREE NICOTINE 1-100 + WETTING AGENT
40% ANABASINE SULFATE 1-200 + PEANUT OIL
40% ANABASINE SULFATE 1-200 + WETTING AGENT
DERRIS .025% ROT + PEANUT OIL
DERRIS .025% ROT. + WETTING AGENT
UNTREATED CHECK

FIG. 4.—Results of a number of tests with derris, nicotine and anabasine, used with and without oil emulsions, against the squash bug.

placed in the constant temperature cabinet, as was done with the cages in the tests with squash bugs. They were confined thus for two hours to insure drying of the material and were then removed from the holders and placed in cylindrical

Table 1.—Toxicity to adult squash bugs of derris, anabasine sulfate, nicotine, nicotine sulfate and pyrethrum when used in emulsions with certain oils.

Material	Dilution (Water Spray Unless Noted)	Oil Added[1]	80° F. and 40% Relative Humidity			80° F. and 70% Relative Humidity			
			Bugs Used, Number	Dead After 48 Hours, Per Cent	Dead After 72 Hours, Per Cent	Bugs Used, Number	Dead After 48 Hours, Per Cent	Bugs Used, Number	Dead After 72 Hours, Per Cent
Derris	0.025% rotenone	No oil or wetting agent	300	1	2	356	3	153	1
		Tung				101	2	101	3
		Teaseed	101	15	18	102	18	102	22
		Corn	101	5	8	101	13	101	15
		Peanut	250	56	68	352	58	150	65
		Olive	101	26	35	101	20	101	31
		Petrolatum	101	19	24	99	16	99	18
		Wetting agent only	200	1	3	101	6	101	7
		Soybean				97	3	97	4
		Check (no treatment)	*100*	*1*	*2*	*305*	*1*	*100*	*1*
Derris-acetone extract	0.015% rotenone	No oil or wetting agent	102	100	100				
		Peanut	101	100	100				
		Petrolatum	98	100	100				
	0.0075% rotenone	No oil or wetting agent	102	39	78				
		Peanut	99	54	84				
		Petrolatum	100	54	79				
Derris plus acetone	0.0125% rotenone	No oil or wetting agent	100	84	90				
		Peanut oil	102	95	97				
		Petrolatum	100	84	87				
Derris	0.0125% rotenone	No oil or wetting agent	100	2	2				
Acetone-water	2.5% spray	No oil or wetting agent	101	1	2				
		Check (no treatment)	*101*	*3*	*5*				
Derris dust plus wetting agent[2]	0.75% rotenone		52	4	6				
		Check (no treatment	*51*	*2*	*2*				
Anabasine sulfate	1–200	No oil or wetting agent	252	3	4	253	7	151	8
		Teaseed	152	43	52	100	47	100	51
		Corn	149	32	38	101	33	101	36
		Peanut	250	58	66	253	66	151	67
		Olive	152	32	40	101	31	101	37
		Petrolatum	153	11	15	101	9	101	12
		Tung	101	4	7	101	9	101	9
		Wetting agent only	200	3	4	101	4	101	4
		Check (no treatment)	*151*	*2*	*3*	*51*	*2*	*51*	*4*
Free nicotine	1–100	No oil or wetting agent	252	1	1	300	3	149	4
		Teaseed	149	25	40	101	28	101	41
		Corn	150	9	11	100	12	100	17
		Peanut	251	47	69	404	61	151	63
		Olive	151	5	9	103	10	103	14
		Petrolatum	151	1	1	100	9	100	10
		Tung	154	6	10	102	8	102	14
		Wetting agent only	249	2	3	150	4	100	8
		Check (no treatment)	*202*	*2*	*2*	*49*	*0*	*49*	*0*
Nicotine sulfate	1–100	No oil or wetting agent	99	16	20	99	14	99	19
		Teaseed	101	70	72	101	71	101	78
		Corn	103	19	21	101	15	101	15
		Peanut	100	63	71	100	81	100	83
		Olive	101	65	67	100	59	100	61
		Petrolatum	99	15	16	100	15	100	17
		Tung	97	9	10	98	11	98	14
		Wetting agent only	101	23	30	101	24	101	27
		1% Soap chips[3]	101	50	56	101	45	101	49
		Check (no treatment)	*100*	*1*	*2*	*50*	*0*	*50*	*0*
Pyrethrum-acetone extract	0.0213% pyrethrins I and II	1% soap chips[3]	50	92	90[4]				
	0.0106% pyrethrins I and II	1% soap chips	50	74	78				
	0.0053% pyrethrins I and II	1% soap chips	99	55	55				
Commercial pyrethrum[5] dust 1 part, talc 5 parts	Dust		51	88	76[4]				
		Check (no treatment)	*50*	*2*	*2*				

[1] Technical sodium lauryl sulfate used as an emulsifying agent with all oil sprays except those containing the derris-acetone extract, where triethanolamine oleate was used.
[2] Technical sodium oleyl sulfate.
[3] Commercial white floating soap chips.
[4] Some bugs counted as dead recovered.
[5] Manufacturers claim 2 per cent pyrethrins I and II

screen cages. A piece of moist cotton in a watch glass covered with a wire screen provided water, which the individuals were able to reach with their mouth parts but not with other parts of the body.

DISCUSSION OF RESULTS.—The results

obtained with the squash bug are presented in table 1 and also partially in fig. 4. To summarize briefly: the toxicity of derris, nicotine, nicotine sulfate and anabasine sulfate was markedly increased by the use of oils, especially peanut oil. Also, the toxicity of derris was greatly increased when acetone was added to the powder 24 hours before use, and still further increased when peanut oil was used. Freshly prepared derris extract was very effective. The vegetable oils increased the toxicity a much greater degree than the mineral product.

The results obtained with the milkweed bug are given in table 2. The insect is not so resistant to insecticides as is the squash bug, and it is relatively more susceptible at the higher humidity. In the few tests with the milkweed bug presented here it appears that mineral oil is practically as effective as the peanut oil, but this was not the case in tests with the squash bug. However, all of the oils increasethe toxicity of derris.

Foliage tests in the field on five varieties of half grown squash plants indicate that two applications of sprays containing derris (0.015 per cent rotenone) and 1 per cent of one of the following oils were not injurious to the plant: olive, peanut, tea-seed and petrolatum.—1-7-38.

Table 2.—Toxicity tests with measured doses of derris[1]-oil mixtures on individual milkweed bugs.

Concentration of Oil in Mixture, Per Cent	Concentration of Sodium Lauryl Sulfate, Gram Per Liter	Relative Humidity (80° F.), Per Cent	Oil	Bugs Used, Number	Dead After 24 Hours, Per Cent	Dead After 48 Hours, Per Cent
1	0.3	50	None, wetting agent only	100	8	55
			Corn	100	9	62
			Cottonseed	100	12	73
			Petrolatum	100	14	81
			Peanut	100	56	94
			Olive	100	11	78
			Linseed	100	11	66
			Check (no treatment)	*100*	*0*	*1*
2	0.3	50	None, wetting agent only	101	9	58
			Corn	99	11	66
			Cottonseed	102	19	95
			Petrolatum	103	21	97
			Peanut	105	84	100
			Olive	101	17	82
			Linseed	98	16	83
			Check (no treatment)	*101*	*0*	*0*
1	0.1	70	Petrolatum	148	—	100
			Peanut	149	—	100
			Teaseed	152	—	100
			None, wetting agent only	146	—	76
			Check (no treatment)	*151*	—	*6*
1	0.3	50	None, wetting agent only	55	25	62
			Peanut	54	90	100
			Crude peanut	51	94	100
			Peanut oil fatty acids	56	88	100
			Peanut oil, without derris	50	14	18
			Crude peanut oil, without derris	52	34	36
			Peanut oil fatty acids, without derris	55	35	38
			Check (no treatment)	*56*	*0*	*2*

[1] The rotenone content of all the sprays containing derris was 0.01 per cent.

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The Particle Size of Commercial Insecticidal Sulfurs as Determined by Sedimentation Analysis

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It is now generally agreed that the insecticidal and fungicidal efficiency of powdered sulfur is dependent on the state of subdivision. Wilcoxon & McCallan (1931) showed by laboratory tests that the fungicidal action of sulfur is directly proportional to the number of particles in a given area. Tests against the citrus thrips, *Scirtothrips citri* (Moult.), by McGregor (1931, 1934) show that the finer sulfur dusts are most effective. Also it has been stated by Young & Tisdale (1929) and by Streeter & Rankin (1930) that particles larger than 27 microns in diameter (theoretical 600 mesh) are of no value, since they will not adhere to plant foliage.

The demand for finer sulfur dusts led to the need for a practical means of measuring the particle size. A frequently used means of estimating fineness is to sieve through a 325-mesh screen, but this does not give definite information concerning the relative proportions of the sizes below 45 microns, commonly believed to be most effective. Actual counts under the microscope give fairly reliable information, but the method is too time consuming to be suited for routine determinations. Information on the subsieve fineness, similar to that obtained by direct microscopic measurement, can be obtained by sedimentation analysis, but this method has been used very little for sulfur.

Two preceding papers have recorded the particle size of commercial calcium arsenates (Goodhue 1937) and Paris greens (Goodhue & Gooden 1937) as determined by sedimentation analysis. In this paper the method is applied to the commercially available insecticidal sulfurs. The percentage passing a 325-mesh screen has also been determined for comparison with a nearly corresponding fraction obtained by sedimentation. The 44 samples examined were obtained from 16 manufacturers. All but two of the samples (nos. 31 and 32) were either pure sulfur or sulfur containing about 5 per cent inert material, which is usually added as a conditioning or wetting agent.

PARTICLE SIZE DISTRIBUTION.—The sedimentation apparatus and the procedure reported by Goodhue & Smith (1936) were used for the mechanical analysis. The sedimentation was carried out in 50 per cent ethyl alcohol maintained at 30 degrees C. by a controlled water bath. A mixture of saponin and ammonium caseinate in slightly ammoniacal solution was found to be a good dispersing agent and stabilizer for all the various types of sulfur regardless of the foreign material present.

Since dispersion and stabilization are very important in a sedimentation analysis, and particularly so with sulfur, complete details of the method of dispersion will be given.

The dispersing apparatus consists of a brush, with soft bristles about three-fourths inch long, which revolves in a dented test tube about seven-eighths inch in diameter, the top of which is fused to a funnel made by blowing the bottom out of a 250 cc. Erlenmeyer flask. Except for the dents in the tube this apparatus is similar to the one used by Wagner (1933) for the dispersion of cement samples. A sample of the correct weight to give about a 1 per cent suspension in the sedimentation apparatus (4 grams in 400 cc.) is placed in the dispersing tube, and

Table 1.—Particle size distribution and percentage above 325 mesh in sulfur insecticidal samples.

CLASS	SAMPLE NO.	PERCENTAGE ABOVE 325 MESH	PERCENTAGE BETWEEN INDICATED DIAMETERS						
			Above 40μ	40–30μ	30–20μ	20–15μ	15–10μ	10–4μ	Below 4μ
Colloidal suspension	1	—	0.7	0.5	0.0	0.5	0.5	10.0	87.8
Flotation paste	2	1.0	0.0	2.0	0.0	2.5	1.5	14.0	80.0
	3	0.4	0.0	0.0	0.0	0.0	0.0	54.5	45.5
Special process	4	0.0	0.8	0.5	1.3	4.0	18.0	53.0	22.4
	5	6.0	6.0	1.2	1.2	1.3	1.3	69.5	19.5
Ground:									
Conditioned	6	2.0	6.5	9.5	10.5	14.5	20.0	21.5	17.5
			8.0	6.5	14.5	9.5	18.5	24.0	19.0
	7	1.4	0.0	2.5	8.0	12.0	35.5	21.0	21.0
	8	1.0	0.5	2.5	14.5	13.0	19.5	36.5	13.5
	9	0.3	3.5	2.5	16.0	14.5	23.5	28.5	11.5
	10	1.3	5.5	2.5	12.0	6.5	13.5	31.5	28.5
	11	4.8	17.0	8.5	17.0	17.0	19.5	11.5	9.5
	12	2.2	6.5	6.5	16.0	14.5	14.5	29.0	13.0
			4.0	9.5	12.0	18.5	14.5	29.0	12.5
	13	0.5	1.5	5.0	21.0	22.0	13.5	21.0	16.0
	14	2.6	16.0	5.0	18.0	15.0	21.0	11.0	14.0
	15	0.1	11.0	5.0	19.0	21.0	16.0	20.0	8.0
	16	3.4	11.5	7.5	19.0	12.5	16.0	16.0	17.5
	17	0.6	3.5	6.5	16.5	16.5	18.0	25.0	14.0
			5.0	6.5	15.0	16.5	16.5	25.0	15.5
Wettable	18	2.5	3.5	5.0	14.5	11.5	28.5	22.0	15.0
	19	0.7	5.0	5.5	10.5	17.0	25.0	18.5	18.5
	20	1.0	13.0	10.0	27.5	27.5	11.0	5.0	6.0
	21	3.6	5.0	6.5	13.5	12.5	17.5	30.0	15.0
	22	0.3	1.0	5.0	10.0	7.5	26.0	39.5	11.0
			0.0	1.5	9.5	8.0	19.0	44.0	18.0
	23	2.3	4.0	9.5	16.0	6.5	17.5	26.5	20.0
Pure	24	0.3	0.0	1.5	6.5	4.0	27.5	39.5	21.0
	25	14.5	24.0	22.0	25.0	12.0	7.0	10.0	0.0
	26	7.8	6.5	5.0	16.0	16.0	22.5	20.0	14.0
	27	1.5	6.5	3.0	20.0	9.5	25.0	5.5	30.5
	28	0.9	5.5	5.5	19.0	12.0	25.5	17.5	15.0
			8.0	8.0	18.5	14.5	28.0	9.5	13.5
	29	1.0	8.0	6.5	24.0	16.0	21.5	9.0	15.0
	30	0.5	9.5	8.0	25.0	17.5	17.0	9.0	14.0
Crude	31	12.0	32.0	5.5	13.5	13.5	11.5	16.0	8.0
	32	20.0	29.0	2.5	13.0	6.5	11.0	15.0	23.0
Sublimed flowers	33	0.2	0.0	5.5	37.5	29.5	13.5	8.0	6.0
	34	0.3	0.0	8.0	24.0	35.0	14.0	10.5	8.5
			1.5	6.5	27.0	35.0	12.0	12.0	6.0
	35	3.0	7.5	16.0	11.0	21.0	7.5	12.5	24.5
	36	6.5	15.0	12.5	11.0	5.0	21.0	3.5	32.0
	37	24.0	25.0	5.5	10.5	6.5	18.5	10.5	23.5
			24.0	5.5	13.0	5.5	16.0	13.5	22.5
Mixtures:									
Ground and flowers	38	5.4	12.5	21.0	35.0	7.5	12.5	7.5	4.0
Dried flotation and ground wettable	39	2.8	5.0	9.0	15.0	17.5	15.0	28.0	10.5
	40	3.0	7.5	17.5	16.0	7.5	12.5	18.5	20.5
Dried flotation and ground conditioned	41	2.6	0.0	5.5	16.0	16.0	14.5	28.0	20.0
Ground and zinc oxide (10 per cent)	42	1.9	1.0	8.5	14.0	12.5	19.0	30.0	15.0
Dried precipitated and ground, conditioned	43	1.3	3.5	7.5	11.0	17.5	16.0	30.0	14.5
Dried precipitated and ground, wettable	44	1.5	3.5	5.0	11.0	14.0	12.5	37.5	16.5

10 cc. of water is added from a pipette. The brush is introduced and run from four to five minutes at the rate of 800 revolutions per minute.

A sample containing a wetting agent can be dispersed without the addition of the other wetting agents. As a stabilizer a mixture containing 2.5 cc. of 4 per cent saponin solution in 50 per cent alcohol, 2.5 cc. of 4 per cent ammonium caseinate suspension in 50 per cent alcohol and 5 drops of ammonia (sp. gr. 0.90) is slowly added near the end of the dispersion period. If the sample does not contain a wetting agent, a small portion of this mixture must be added at the beginning of the stirring, and the remainder near the end. The dispersed sample is quantitatively transferred to the sedimentation apparatus, diluted to the proper volume and mixed. Ten cubic centimeters of 95 per cent alcohol must be placed in the sedimentation apparatus to offset the 10 cc. of water used in the dispersion. The procedure from here is given in the article already cited (Goodhue & Smith 1936).

If the mechanical action is vigorous enough to give good dispersion, there is always the possibility of grinding. In this method, however, the action of the brush appears to be primarily one of dispersion. For example, the same sample gave nearly identical results when brushed two and a half, five and ten minutes. Also a microscopic comparison of dry dusted slides with those dispersed by this method showed about the same number of large particles, although the number of very small particles was much greater in wet dispersion.

A method similar to that proposed by Odén (1916) was used to calculate the particle size distribution. For this purpose the density of each sample was determined in 95 per cent alcohol. Only four of the samples varied more than 0.03 from 2.07 grams per cubic centimeter, which is the theoretical density for the rhombic form; for these the densities were as follows: no. 20, 1.96; no. 40, 2.13; no. 42, 2.14; and no. 23, 1.93 grams per cubic centimeter. Seven samples were run in duplicate to indicate the precision that can be expected. Variations as much as 4 per cent from the mean sometimes occur. This is attributed to the method of calculation; the actual sedimentation curves check closely (2 per cent or better).

PERCENTAGE PASSING A 325-MESH SIEVE.—A 5-gram sample in 10 cc. of 95 per cent alcohol saturated with sulfur was dispersed by brushing five minutes in the apparatus described above. The dispersed sample was quantitatively transferred to a 325-mesh A.S.T.M. sieve, and the fine particles were washed through with saturated 95 per cent alcohol while being gently stirred with a soft brush. The dispersion was so nearly complete that very little alcohol was required. The coarse material was transferred to a sintered glass crucible, dried and weighed. The results are expressed as the percentage that does not pass a 325-mesh sieve, to permit comparison with the similar fraction (above 40 microns) obtained by sedimentation analysis. Checks to less than 0.5 per cent are usually obtained unless 20 per cent or more of the sample is above 325 mesh, in which case the precision is about 1 per cent.

LOOSE BULKING VALUE.—The loose bulking value gives a rough measure of the particle size for some insecticides. For these samples of sulfur the values ranged from 30½ to 73 cubic inches per pound. In general the finer materials gave the highest bulking value, but the correlation with the particle size by sedimentation analysis or with the values obtained with a 325-mesh sieve was so poor that the figures are not given.

ANGLE OF SLOPE.—Wilcoxon & McCallan (1931) measure the base angle of a cone formed by allowing dust to flow through a funnel supported above the center of a metal disk. When no greater altitude is gained by further addition of dust, the angle of slope of the pile is calculated. This angle gives the relative dustability of finely divided materials. Dusts that flow easily and disperse well give a low angle of slope. This is important in dusting sulfurs. As determined on these samples, the values vary from about 40 degrees for the best conditioned sulfur to 70 degrees or more for the untreated samples. There appears to be no correlation with particle size in a group of samples as varied as this one.

DISCUSSION OF RESULTS.—The results on the 44 samples of sulfur are given in table 1. The graphical method of presenting the data on the particle-size distribution is very useful as a means of comparing the fineness unless the number

of samples is too large to be presented on one graph. In fig. 1, 11 samples scattered over the entire range are compared. They include all the finest samples, some medium, and some coarse samples. The curves at the upper left represent the finest samples and those at the lower right the coarsest. Considerable variation in particle size is indicated, but the a large proportion of very coarse material. The class of pure flowers of sulfur is variable; some samples contain considerable fine material while others contain very little. The last class is a group of mixtures showing considerable variation in particle size distribution because of variations in the components. The only dried flotation sulfur is in some of these

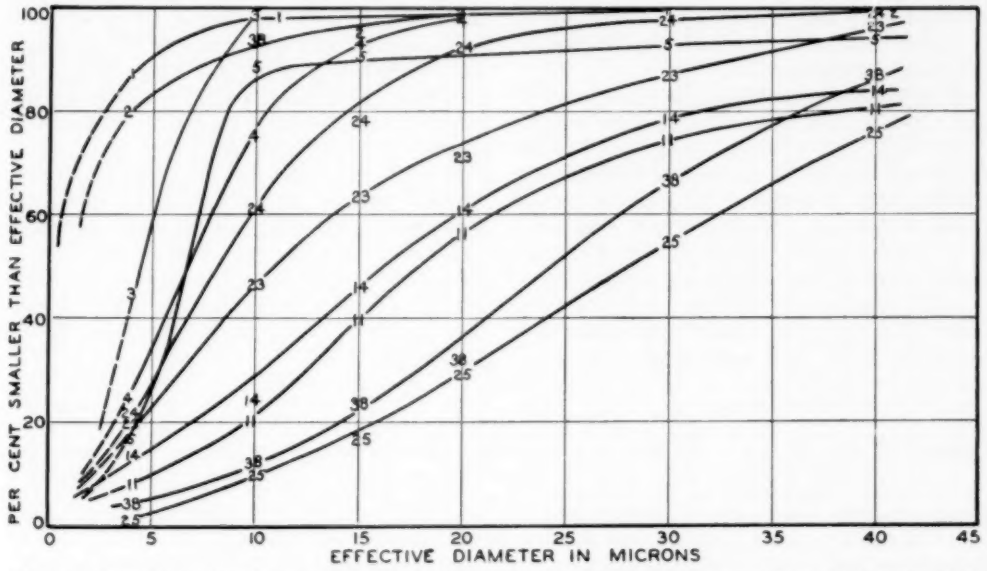

FIG. 1.—Cumulative frequency curves showing the percentage smaller than any effective diameter of 11 samples of commercial sulfur. The numbers, which are identical with the sample numbers, show by their position the points determined experimentally.

largest number of samples are about medium and appear in the range between nos. 11 and 23.

For convenience in discussing the results, the 44 samples are divided into six classes according to the method of manufacture. As would be expected, the colloidal suspensions have the largest percentage of material below 10 microns in diameter. The flotation pastes are very fine, but not so fine as the colloidal suspensions. Next in order and still very fine are two samples, nos. 4 and 5, made by a special process. The ground sulfurs are next in order and are in general about medium in this group of samples. However, no. 24, a pure ground sulfur, is one of the finest in this class, even approaching nos. 4 and 5. This indicates that a very fine sulfur can be produced by this method. Two samples of ground crude (commercial) sulfur, nos. 31 and 32, have mixtures, and it appears to increase the amount of fine material. Except for sample no. 38, this group is about medium or slightly finer in particle size.

If the samples were judged by the percentage passing or retained on a 325-mesh screen, the picture would be very different. Under identical conditions where only the grinding time is varied, these results should have some significance, but for samples prepared by different methods, or by a similar method in the hands of different manufacturers, such a comparison may be entirely misleading. For example, no. 5 has 6 per cent above 325 mesh and 89 per cent below 10 microns. This might lead one to believe the sample is as coarse as no. 38, with 5.4 per cent above 325 mesh and only 11.5 per cent below 10 microns. Sample no. 33 has only 0.2 per cent above 325 mesh; yet it is very coarse, with only 14 per cent below

10 microns. Nos. 32 and 37 have as much as 20 and 24 per cent, respectively, above 325 mesh but still have 38 and 35 per cent below 10 microns.

As was expected, the percentage above 325 mesh is in fair agreement with the coarsest fraction (above 40 microns) by sedimentation. Although these two fractions cannot be directly compared because of variations in the screen (Dunn 1930; Fritts 1937), the results by sieving serve to some extent as a check on the sedimentation analysis.

The method of determining the particle size distribution by sedimentation analysis as reported in this paper appears to be the most practical means of estimating the fineness of a sulfur sample. As compared with the method of direct measurement under a microscope this method has many advantages, especially with respect to time consumed, the chance of getting an average sample, and even the accuracy of the results. The advantages of sedimentation analysis have already been pointed out and discussed fully by Borchers & May (1935).

SUMMARY.—The particle size distribution in 44 samples of commercial insecticidal sulfur has been determined by sedimentation analysis. A new method of dispersion in which is used a wetting agent composed of a mixture of saponin and ammonium caseinate in ammoniacal 50 per cent alcohol was found to give very good results on a wide variety of samples. The flotation pastes and suspensions of colloidal sulfur were found to contain the most fine material. A material made by a special process ranks next. Except for two coarsely ground crude samples, the ground sulfurs fall in about a medium fine class. The sublimed flowers are variable and may be either fine or coarse. The percentage through 325 mesh was found to give very little indication of the amount of very fine sulfur in a sample.—1-7-38.

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THE CENTRAL PLANT BOARD at its meeting at Columbus, Ohio, on March 2 condemned two state quarantines as contrary to quarantine principle set forth by the National Plant Board on July 25, 1931; namely, that the aim of quarantine is to prevent spread of plant insect pests and diseases new and /or not widely disseminated. In one instance, the Board pointed out, marketing and grading requirements had been incorporated in pest control regulations, and in another instance fumigation had been required of host plants of a pest in shipments from areas far removed from any known infestation.

Conditioning Agents for Increasing the Effectiveness of Rotenone-Bearing Dusts Against the Pea Aphid*

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The first field tests made at the laboratory at Madison, Wis., in 1935 with a derris dust mixture against the pea aphid, (*Illinoia pisi* (Kltb.), on canning peas were not completely satisfactory. Now and then a test resulted in satisfactory control, but the majority of tests resulted in mortalities of approximately 50 per cent. This dust mixture was composed of ground derris root containing various percentages of rotenone, with one of two types of clay as the diluent. Since 1935 only talc has been used as the diluent for derris or cubé dust mixtures in experiments reported in this paper. Derris was used exclusively in the greenhouse experiments reported in this paper, whereas both derris and cubé were used in field experiments.

It occurred to the authors that the addition of a small quantity of some spreading and wetting agent to the derris dust mixture might so condition it as to make it spread more uniformly on the plants, improve its hygroscopic qualities and increase its effectiveness against the aphid.

Greenhouse Experiments.—Experiments were begun in the winter of 1935 in the greenhouse. In these experiments, small quantities of a spreading and wetting agent greatly diluted in water were incorporated in a derris-talc mixture by employing a mortar and pestle, after which the mixture was spread on papers in a thin layer and partially dried out. In 1936 a power rotary mixer containing stones was devised, with which larger quantities of dust could be mixed (Bronson 1936). In 1937 a still larger dust mixer, fashioned from a concrete mixer, was built. With this apparatus it is possible to mix at one time as much as 60 pounds of dust or as little as 10 pounds, and it is a simple operation to atomize conditioners, very slightly diluted with water, into the ingredients while they are being mixed. When such a dust mixture is thoroughly prepared, it is slightly damp but does not need to be dried before use.

In greenhouse experiments all derris dust mixtures were made up to contain 0.4 per cent of rotenone. This relatively low rotenone content was necessary in order to demonstrate significant differences between a plain dust mixture and several conditioned mixtures. Thus, the greenhouse group of experiments was not designed primarily to find out the effect of derris upon the pea aphid, but to study the supplementary effect upon the aphid of spreading and wetting agents and of other toxic materials incorporated in a derris dust mixture.

Results obtained in 1936 and 1937 with these conditioned derris dust mixtures under greenhouse conditions were very satisfactory. A consistently higher percentage of aphids was killed in a shorter period of time than had been possible before conditioners were employed.

The aphid mortality obtained with these dust mixtures was not rapid as a rule for the first few days after they were applied, but it progressed until after a period of five to seven days such mortality averaged close to 90 per cent. In the field the mortality usually attained 90 per cent or over in approximately two days.

Because of a realization by the authors of the advantage under commercial conditions of even more rapid aphid mortality than had already been experienced with these conditioned derris dust mixtures, a new group of experiments was begun. Nicotine, pyrethrum and other toxic materials, such as aliphatic thiocyanates, were added to conditioned derris or cubé dust mixtures in the belief that such materials might increase the effectiveness of the dust mixtures still further. These experiments were conducted in the greenhouse first and later in the field.

In general, under greenhouse conditions the results obtained with nicotine and pyrethrum as added toxic materials to a conditioned derris dust mixture were satisfactory, and each dust mixture effected a mortality ranging from 75 to 100 per cent.

The addition of a proprietary aliphatic

* The experiments reported upon in this paper were performed in cooperation with the Wisconsin Agricultural Experiment Station.

Table 1.—Summary of results of 29 groups of tests with derris dust mixtures against the pea aphid on potted peas in the greenhouse, Madison, Wis., March, 1936, to March, 1937. (Talc was employed as the diluent for all the dusts.)

Group No.	Treatment	Number of Tests	Total Number of Aphids	Average Per Cent Mortality of Aphids After	
				2 days	5 days
1	Derris dust (0.4% rotenone); an aliphatic thiocyanate, 1.5%; a sodium oleyl sulphate, 1%	4	548	97.0	99.0
2		4	504	100.0	100.0
3		5	245	85.0	100.0
4		5	450	92.0	98.0
5		13	1755	98.0	100.0
6		4	610	90.5	100.0
7		11	1706	93.5	—
8		4	505	97.0	98.0
	Totals and averages, groups 1–8	*50*	*6323*	*94.0*	*99.0*
9	Derris dust (0.4% rotenone), a 50% solution of free nicotine, 1½%; a sodium oleyl sulphate, 1%; water, 2%	12	1465	92.0	92.0
10		9	1315	91.0	91.0
	Totals and averages, groups 9–10	*21*	*2780*	*91.5*	*91.5*
11	Derris dust (0.4% rotenone); a concentrated pyrethrum extract (4.3% pyrethrins), 2%; a sodium oleyl sulphate, 1%	8	1500	85.0	88.0
12	Derris dust (0.4% rotenone); a sodium oleyl sulphate, 1%; water 2%	6	678	61.0	95.0
13		14	1733	80.0	88.5
14		11	1035	57.0	82.0
15		11	1954	78.5	—
	Totals and averages, groups 12–15	*42*	*5400*	*69.0*	*88.5*
16	Derris dust (0.4% rotenone)	5	680	50.0	—
17		6	635	31.0	46.5
18		6	700	43.0	—
19		4	555	38.5	61.5
	Totals and averages, groups 16–19	*21*	*2570*	*40.5*	*54.0*
20	Check—Talc; an aliphatic thiocyanate, 1.5%; a sodium oleyl sulphate, 1%	6	965	22.0	25.0
21	Check—Talc; a sodium oleyl sulphate, 1%; water, 2%	6	1075	2.7	*
22	Check—Talc	6	960	2.0	*
23		2	234	2.5	*
	Totals and averages, groups 22–23	*8*	*1194*	*2.0*	—
24	Check—No treatment	4	915	0.5	*
25		21	3310	3.0	*
26		2	410	1.0	*
27		15	1395	5.5	*
28		7	785	2.0	*
29		10	815	5.0	*
	Totals and averages, groups 24–29	*59*	*7630*	*3.0*	—

* Population exceeded the original infestation. The increase frequently was nearly 100 per cent, depending upon the original number of aphids and whether or not the plants began to wilt in the presence of a heavy infestation.

thiocyanate to a conditioned derris dust mixture resulted in the highest average mortality attained by any combination and, furthermore, resulted consistently in higher aphid mortalities at lower temperatures than were obtained with conditioned dust mixtures to which nicotine or pyrethrum had been added. The com-

bination with the thiocyanate resulted in much more rapid mortality of aphids than was experienced with derris dust mixtures conditioned only with a sodium oleyl sulphate.

Results of greenhouse tests, accumulated over the period of a year, appear to reveal clearly the relative effectiveness of (1) conditioned derris dust mixtures to which nicotine, pyrethrum or an aliphatic thiocyanate was added, (2) conditioned derris dust mixtures alone (conditioned with a sodium oleyl sulphate) and (3) plain derris dust mixtures, when the three are compared with proper checks.

Many of the tests were staged purposely under different temperature and humidity conditions. Nearly all dust mixtures resulted in increased aphid mortality under conditions of high temperature and/or high relative humidity. Therefore, tests in which these conditions occurred have been omitted from the following table. For the tests tabulated, the range in temperature was from 53 degrees to 72 degrees F.; the range in relative humidity was from 30 to 78 per cent.

A summary of 29 groups of tests involving over 30,000 aphids is presented in table 1.

DISCUSSION OF RESULTS.—The derris dust mixture conditioned with a spreading and wetting agent and reinforced with an aliphatic thiocyanate resulted in a mortality of the aphids involved in these tests which averaged 94 per cent after two days and 99 per cent after five days.

A similar dust mixture reinforced with free nicotine in place of the aliphatic thiocyanate resulted in an average mortality of 92 per cent after two days and 91 per cent after five days.

A similar dust mixture reinforced with concentrated pyrethrum extract in place of the aliphatic thiocyanate resulted in an average mortality of 85 per cent after two days and 88 per cent after five days.

The derris dust mixture conditioned only with a spreading and wetting agent —referred to in a previous publication as "special dust" (Dudley, Bronson & Carroll 1937)—exhibited a decidedly lower mortality after two days than the first three dust mixtures. After five days, however, the mortality effected by this dust mixture had increased to such an extent that it approached the mortality effected by the first three.

Plain derris dust mixture exhibited even greater difference in mortality when compared with the fourth dust mixture than is evident when the fourth is compared to the first three.

All five dust mixtures caused a progressive mortality of the aphids apparent throughout the period of the tests, which generally continued for five days.

When used with talc but without derris in the first type of checks, the aliphatic thiocyanate and sodium oleyl sulphate together exhibited an average mortality of 25 per cent after the five day period. None of the other checks exhibited any appreciable mortality, and by the end of five days the aphids present exceeded the original number, frequently by 100 per cent or more.

A greenhouse experiment was staged to test the effect against the pea aphid of three derris dust mixtures conditioned with a sodium oleyl sulphate, to each of which was added one of the three solvents commonly employed in extracting rotenone; namely, acetone, alcohol and carbon tetrachloride. The results revealed practically 100 per cent mortality of the treated pea aphids when the temperature was relatively high, and slightly lower mortality with lower temperatures. These combinations were superior to derris dust mixtures conditioned only with the sodium oleyl sulphate, but were not superior to the dust mixtures to which an aliphatic thiocyanate had been added.

FIELD EXPERIMENTS.—In field experiments since 1935 both derris and cubé have been employed in making dust mixtures. The field data do not reveal any marked or consistent difference between dust mixtures made from either one of the two groups of rotenone-bearing plants. Sometimes derris appeared slightly superior to cubé, sometimes the opposite was apparent and often both appeared to be of equal effectiveness against the pea aphid.

The design of the field experiments was necessarily different from that of greenhouse experiments and, therefore, in the field the rotenone content of the derris or cubé dust mixtures was 0.5 per cent, 0.75 per cent or 1.0 per cent, respectively.

In the field the term *mortality* may be used for the first and second day after treatment because most of the living aphids, from which the mortality is com-

puted, are aphids which survived the treatment. After three or four days, however, and especially after a week or more, the population of the treated plots is made up of aphids which survived, plus those produced by the survivors, which may outnumber the survivors by two or three to one. Thus the term *reduction in the infestation* is more appropriate than the term *mortality*. The percentage reduction in the infestation is obtained by dividing the infestation in the treated plot by that in the check, multiplying by 100 and subtracting from 100 per cent.

Under field conditions the mortality obtained with these conditioned derris or cubé dust mixtures was more rapid than in the greenhouse, the mortality usually attaining 90 per cent or over in approximately two days and progressing until in from five to ten days the reduction in the infestation frequently ranged between 95 and 98 per cent. As a rule, in the field the evidences of toxicity of the derris or cubé did not cease even after the expiration of a 10-day period, but frequently the toxic effects could be detected for two weeks or more after the dust had been applied, through the medium of a lessened rate of reproduction among the remaining adult aphids. Such a progressive reduction in the infestation constitutes a very satisfactory control of the pea aphid.

When the three types of derris or cubé dust mixtures—(1) conditioned dust mixtures to which nicotine or an aliphatic thiocyanate was added, (2) conditioned dust mixtures alone (conditioned with one of several spreading and wetting agents) and (3) plain dust mixtures—were tested under field conditions, the differences were neither as pronounced nor as consistent as they were under greenhouse conditions. The reason for this is very likely the wide range in temperature, relative humidity, wind velocity, plant growth and seasonal aphid behavior experienced in the field during June and July at several locations.

In a rather small number of tests in which free nicotine was added to a conditioned derris or cubé dust mixture, the average reduction in the infestation amounted to 90 per cent.

When conditioned derris or cubé dust mixtures were reinforced by the addition of an aliphatic thiocyanate, the results, without exception, were very satisfactory. In no instance did the reduction in the infestation drop below 90 per cent. In 11 tests of such a mixture containing 0.75 per cent of rotenone, the average reduction in infestation amounted to 95.5 per cent.

In general, derris or cubé dust mixtures conditioned with one of several spreading and wetting agents appeared to be definitely superior to plain dust mixtures. Under some weather conditions, however, both types of dust mixtures resulted in practically the same high percentage of reduction in the infestation. In 12 comparable experiments the conditioned dust mixtures resulted in an average reduction in the infestation of 91 per cent, while the plain dust mixtures resulted in an average reduction of only 79 per cent—a difference of 12 per cent in favor of the conditioned dust mixtures. Such a difference may well be the difference between satisfactory and unsatisfactory aphid control.

In addition to the sodium oleyl sulphate, the authors have tested the following materials, both in the greenhouse and in the field, as spreading and wetting or sticking agents for conditioning derris or cubé dust mixtures: An alkylphenylbenzenesulfonic acid; a sodium lauryl sulphate; a sulfonic acid of an aromatic hydrocarbon in two forms, one a liquid and the other a powder; a sodium salt of sulphonated naphthalene in two forms, one a liquid and the other a powder; a product composed partly of a sodium oleyl sulphate with the addition of some resins; and a sulphonated castor oil.

The majority of these spreading and wetting or sticking agents have given indications of value as conditioners for derris or cubé dust mixtures. None, however, has been superior to the sodium oleyl sulphate.

CONCLUSIONS.—In both the greenhouse and the field, derris or cubé dust mixtures conditioned with a spreading and wetting agent have been shown to be superior, as an insecticide against the pea aphid, to plain derris or cubé dust mixtures. Under field conditions this superiority of the conditioned dust mixtures has amounted to approximately 12 per cent, which may be the difference between satisfactory and unsatisfactory aphid control.

In general, conditioned derris or cubé

dust mixtures reinforced by the addition of nicotine or an aliphatic thiocyanate have been superior to conditioned dust mixtures. This has been especially true in instances where the aliphatic thiocyanate was added.—1-7-38.

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The Fumigation of Insects with Hydrocyanic Acid: Effect of Different Air Pressures

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The customary procedure employed in vacuum fumigation has always been to draw as high a vacuum as possible before the introduction of the fumigant since the natural assumption to make is that the percentage kill obtained with a given dosage of fumigant increases directly as the air pressure decreases. Young, Wagner & Cotton (1935) thus found that a considerably better kill of confused flour beetles, *Tribolium confusum* Duv., was obtained when these insects (in flour) were fumigated with hydrocyanic acid in a 29-inch vacuum than in a 26-inch vacuum. The state of activity of insects is markedly influenced by the amount of air left in the chamber.

When the air pressure in a fumigation chamber is reduced below that of the atmosphere, the activity of the insect first increases and then slowly decreases until the insect is rendered completely inactive, due to lack of air at pressures of 10 millimeters or less. Most species will remain active for some time at air pressures around 60 millimeters. If hydrocyanic acid is more readily taken up by active insects, then better kills would be expected when all of the air is not withdrawn from the system. It was therefore decided to study the effect of air pressure on the mortality of several insects when fumigated with hydrocyanic acid.

The dosages used in this investigation are not applicable to commercial fumigations because, since the purpose was to bring out the effect of hydrocyanic acid on insects at different air pressures, no commodity was present in the chamber and the exposure periods were considerably shorter than those used in commercial practice.

APPARATUS AND EXPERIMENTAL PROCEDURE.—The apparatus used for these experiments, fig. 1, is one designed to measure the sorption of different vapors by insects as well as the amount of vapor necessary to kill the insects under varying conditions. That portion of the apparatus which deals with the measurements of sorption of vapors by insects has already been described by Carpenter & Moore (1938).

The percentage kill of a species of insect at a given air pressure resulting from exposure to a known concentration of hydrocyanic acid is determined as follows: Approximately 100 insects are first placed in the chamber, H, which is fitted with a ground glass joint so that it may be removed from the remainder of the apparatus when desired. The chamber is maintained at the desired temperature (within ± 0.1 degrees C.) during the fumigation period by means of a beaker of water equipped with coils through which water is pumped from a thermostat. The system is then slowly evacuated to the desired air pressure through S_4; this pressure may be read either on the closed-end manometer, D, or on the open-end manometer, J. Steel rulers are fixed in position between the two tubes of the manometers so that the levels of the mercury can be read. Magnifying glasses equipped with cross hairs at the focal

* The writers wish to express their appreciation for the assistance of Dr. N. M. C. Payne in a part of this research.

points are used to obtain the final readings in both cases. These glasses are fastened to small adjustable clamps which can be raised or lowered at will on vertical rods. Ordinarily the closed-end manometer is used to determine the air pressure within the system since it is independent of the atmospheric pressure, but for pressures above 250 mm. it is necessary to use the open-end manometer, J, in connection with an accurate barometer. When the open-end manometer is not in use, S_9 is kept closed with the mercury level in the tube touching the sealed-in glass tip at I as shown in the diagram. If it is desired to use the open-end manometer, S_9 is opened and the leveling bulb is adjusted so that the mercury column touches the tip at I; S_9 is then closed, and the difference in millimeters between the two columns is determined and subtracted from the barometric pressure to obtain the pressure within the system. S_6 is a three-way stopcock; in the first position the insect chamber communicates with the remainder of the apparatus, the gas burette, E, being closed; in the second position the gas burette is connected with the remainder of the system to the right, the insect chamber being closed; the third position connects the insect chamber with the gas burette. After the insect chamber has been evacuated to the desired air pressure, S_6 is changed from the first to the second position and the gas burette is completely evacuated. The quantity of gaseous hydrocyanic acid that is to be used in the

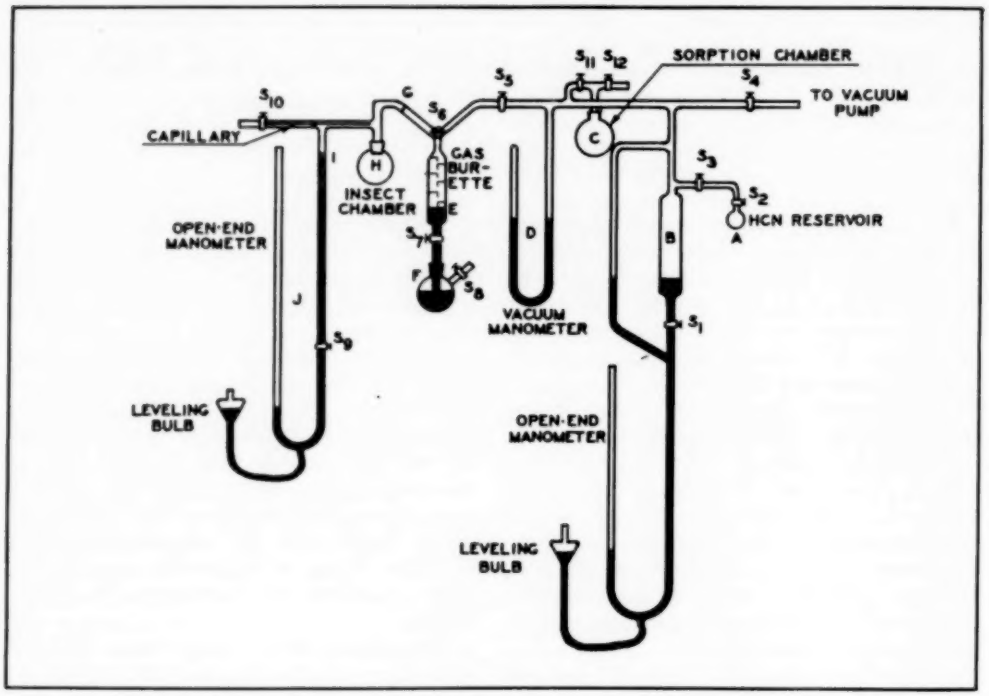

FIG. 1.—Diagram of the apparatus used in the investigation.

fumigation is now measured in the gas burette. Since the volume of this burette has been accurately calibrated from S_6 to the bottom of each of the six tips, the quantity of hydrocyanic acid vapor to be used in the experiment is determined by setting the mercury level to the appropriate tip. This is accomplished by opening S_7, which allows the mercury to rise into the evacuated burette from the reservoir, F, which is at atmospheric pressure. The vapor of hydrocyanic acid is admitted into the burette by opening the stopcocks S_2 and S_3 to the reservoir containing the liquid fumigant. (All of the air has been previously removed from the fumigant reservoir by several evacuations at liquid air temperatures so that,

when S_2 is opened, only the vapor of the fumigant diffuses into the apparatus.) After the vapor has been adjusted to the desired pressure by the raising or lowering of the mercury in the large tube, B, the pressure is read on the closed-end manometer, D. The room temperature near the gas burette is also noted at this point. There is thus enclosed in the gas burette a quantity of vaporized fumigant whose pressure, volume and temperature are known. This vapor is now admitted into the insect chamber by turning S_6 to its third position, and then opening S_7. Since the air pressure in the insect chamber is ordinarily quite low, the mercury rises in the gas burette and glass tube until it reaches the point, G, thus forcing all of the vapor into the chamber, H. S_7 is then closed. In cases where the air pressure in H is above 200 mm., the air pressure in the reservoir, F, is increased above atmospheric pressure so that the mercury will rise to the point, G. Since the volume of the insect chamber is known from the point G to S_{10} and tip I, the pressure of the vaporized fumigant developed in the chamber may be calculated by the equation

$$P_2 = P_1 \cdot \frac{V_1}{V_2} \cdot \frac{T_2}{T_1} \qquad (1)$$

where P_2 is the partial pressure of fumigant over the insects, P_1 is the pressure of fumigant in the gas burette having an absolute temperature T_1 and volume V_1, V_2 is the volume of the insect chamber and T_2 is its absolute temperature. While this equation is strictly true only for the ideal gas, it is sufficiently accurate for our purposes. The partial pressure of hydrocyanic acid in the insect chamber, P_2, is then converted into milligrams per liter. After the vapor has been in contact with the insects for a definite length of time as measured by a stop-watch, the insect chamber is returned to atmospheric pressure by opening S_{10}. The insects are then placed in an appropriate food mixture in small numbered containers.

The method of measuring out the dosage outlined above has the advantage that one concentration may be closely duplicated as many times as necessary and is much more nearly accurate than attempting to measure out a small amount of a volatile liquid such as hydrocyanic acid. Another advantage of the method is that the concentration of hydrocyanic acid in the chamber is built up very quickly to the maximum value by this manner of introducing the vapor into the chamber. The concentration of the hydrocyanic acid in the chamber falls only slightly during the fumigation period due to sorption by the insects and the walls of the container.

The determination of the percentage kills is made several days after the fumigation as it has been found that many insects die from the effects of the poison three or four days after exposure. Counts of the dead and living insects are made on the sixth and eighth days after fumigation for all species except confused flour beetles which are counted on the ninth and eleventh days. The number dying due to the reduced air pressure or to natural mortality is determined for each set of experiments by running a control. It has been found that exposure to a high vacuum for as long a period as an hour and ten minutes has little, if any, effect on the species studied. Hence the controls show one or two per cent dead, and rarely over five per cent. The percentage kills recorded have been corrected for the mortality occurring in the controls.

EXPERIMENTAL RESULTS WITH CONFUSED FLOUR BEETLES.—The results of the experiments obtained with confused flour beetles, *T. confusum*, at different air pressures are given in table 1.

Table 1.—Results of experiments obtained with confused flour beetles fumigated with hydrocyanic acid at several different air pressures.

AIR PRESSURE IN MM. OF MERCURY	PERCENTAGE KILL AT SPECIFIED DOSAGES OF HYDROCYANIC ACID (10-MINUTE EXP. AT 20° C.)			
	0.368 mg./l.	0.395 mg./l.	0.409 mg./l.	0.438 mg./l.
2	43.9	72.2	89.7	100.0
10	—	—	—	90.8
15	22.8	57.1	69.0	—
30	36.7	28.6	58.7	58.9
60	0.0	7.5	47.7	33.4
100				4.5
200				0.0

It will be seen from this table that the kills fall off very decidedly as the air pressure increases. At atmospheric pres-

sure about six milligrams per liter are required to produce a 95 per cent kill of confused flour beetles in a 10-minute exposure period while at 1 to 2 mm. air pressure a dosage of only 0.44 milligrams per liter is sufficient to produce the same kill.

These results are similar to those obtained by Young, Wagner & Cotton (1935) with flour beetles fumigated in flour. The authors attributed the difference in killing efficiency of hydrocyanic acid at different air pressures to the fact that the amount of hydrocyanic acid sorbed by the flour increased as the air pressure decreased. It is obvious that this is not the complete explanation since we have obtained similar results with no flour present in the chamber. Cotton (1932), using fumigants other than hydrocyanic acid, attributed the poorer kills which result at higher air pressures to a physiological effect of oxygen upon the insect. Cotton, Wagner & Young (1937) demonstrated an oxygen effect using ethylene oxide—carbon dioxide mixtures on confused flour beetles.

The effect of air pressure on confused flour beetles fumigated with hydrocyanic acid may be due to such an oxygen effect, or to some physical effect of nitrogen upon the action of hydrocyanic acid, or to a combination of the effects produced by both oxygen and nitrogen. In order to determine whether nitrogen influenced the kill, fumigations with the same dosage were made with and without added nitrogen. Runs 1 and 2, table 2, show that the presence of nitrogen decidedly lowers the percentage kill. Runs 3 and 4 were then made to determine the approximate increase in dosage necessary to overcome the effect of about 760 mm. of nitrogen.

Table 2.—Effect of oxygen and nitrogen on confused flour beetles fumigated with hydrocyanic acid (10-minute exposure at 25 degrees C.).

Run	Air Pressure in Millimeters	Pressure of Added Nitrogen	Total Pressure* in Millimeters	Dosage of HCN in mg./L.	Percentage Kill
1	1–2	—	1–2	0.40	58.4‡
2	1–2	760	762	0.40	0.0‡
3	1–2	764	766	2.00	34.3
4	1–2	755	757	2.20	57.6‡
5	764	—	764	4.10	50.0
6	764	—	764	6.00	94.2
7	1–2	—	1–2	0.44	100.0
8	1–2	60	62	0.45	79.0
9	60	—	60	0.45	33.0

* Excluding the pressure due to hydrocyanic acid.
‡ Runs 1 and 2 are the average of two determinations; run 4 is the average of three determinations.

It was found that it is necessary to increase the dosage approximately five times when nitrogen is present in the chamber in order to obtain a kill comparable to that obtained when no nitrogen is added. To determine whether oxygen had an additional effect, experiments were also made with air in the chamber (runs 5 and 6). When these experiments are compared with runs 3 and 4, in which there was approximately the same amount of nitrogen, it is found that it is necessary to double the dosage in order to obtain a comparable kill in the presence of air. Similar results were obtained in runs 7–9 with lower pressures of nitrogen and air.

The effect of air pressure obtained with confused flour beetles, table 1, is therefore due to the presence of nitrogen as well as oxygen. Both gases are responsible for the reduction of the kill obtained with a given dosage of hydrocyanic acid as the air pressure increases. The effect of nitrogen is probably physical, whereas that of oxygen is probably both physiological and physical.

EXPERIMENTAL RESULTS WITH RICE WEEVILS.—The results of the experiments obtained with rice weevils, *Sitophilus oryzae* (L.), at different air pressures are given in table 3. Since the percentage kills listed are in a great many cases the average of several experiments, the number from which the average is taken is given in parentheses immediately

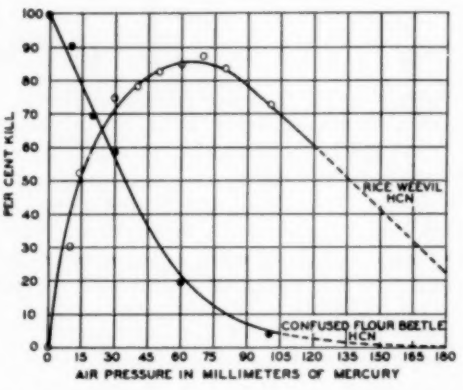

FIG. 2.—Percentage kills of rice weevils and confused flour beetles obtained at different air pressures. Dosage of hydrocyanic acid equals 4.65 mgs./liter for rice weevils and 0.438 mgs./liter for confused flour beetles.

following the percentage kill. It will be seen that reducing the air pressure has the same effect on the kill of rice weevils as it has with confused flour beetles down to a pressure of about 60 mm. of mercury. Below this point, however, the kill obtained with rice weevils falls off rapidly until no kill is obtained at 1–2 mm. air pressure, whereas the percentage kill obtained with confused flour beetles reaches its maximum at this very low pressure, fig. 2. In order to obtain a kill of 95 per cent with rice weevils at an air pressure of 1–2 mm., it is necessary to increase the dosage of hydrocyanic acid up to about 250 milligrams per liter (in a 10-minute exposure period); this dosage is 36 times greater than that necessary to produce a 95 per cent kill at 40 to 80 mm. air pressure, table 3.

Table 3.—Rice weevils fumigated with hydrocyanic acid at several different air pressures.

Air Pressure in mm. of Mercury	Percentage Kill at Specified Dosage of HCN (10-Minute Exposure at 20° C.)		
	3.19 mg./l.	4.65 mg./l.	7.15 mg./l.
2	0.0	0.0	0.0
10	—	30.9 (2)†	37.2 (2)†
14	—	52.3 (2)	—
20	66.2 (1)†	69.6 (3)	83.2 (4)
30	—	74.7 (1)	—
40	80.3 (1)	78.1 (2)	98.9 (1)
50	—	82.2 (4)	—
60	79.4 (3)	84.8 (2)	96.4 (2)
70	—	87.5 (1)	—
80	83.3 (1)	83.9 (2)	94.4 (3)
100	62.5 (1)	72.5 (1)	90.7 (2)
150	—	—	69.6 (1)
200	—	—	43.6 (1)
400			17.9 (1)
760			0.0 (1)

† The numbers in parentheses indicate the number of runs averaged to obtain the recorded percentage kill.

CONFUSED FLOUR BEETLES AND RICE WEEVILS COMPARED.—Both rice weevils and confused flour beetles become inactive as the pressure is reduced below 60 mm. until at 1–2 mm. they are completely inactive. The poor kill of rice weevils at 1–2 mm. air pressure may be due to the inactivity of the insect, or may be caused by some mechanical change due to the low pressure, such as the collapse of the tracheae. To eliminate this possible pressure effect, experiments were performed in which rice weevils were rendered inactive at 60 mm. air pressure by allowing them to remain at this pressure until they had used up all of the oxygen. (This required a period of about three hours.) By comparing the results of these experiments with those on active insects at the same pressure, table 4, it will be seen that the active insects are much more easily killed. This of course is not true for confused flour beetles, which are most easily killed when they are completely inactive at air pressures of 1–2 mm.

Table 4.—Effect of rendering rice weevils inactive at 60 mm. air pressure before fumigating with hydrocyanic acid (20 degrees C.).

Run	Condition of Insect	Dosage in mgs./l.	Exposure Mins.	Dead	Alive	Per centage Kill
1	Inactive	49.0	41	637	728	46.50
2	Active	49.5	41	1389	2	99.86†
3	Inactive	55.1	41	659	506	56.60
4	Active	55.0	41	1249	2	99.84†

† It should be pointed out that a kill of 100 per cent would have been obtained at a much lower dosage, say about 20 mg./l., in runs 2 and 4 if all the rice weevils had been active when they were fumigated. Since a large number of insects were used in these experiments in a small chamber, the two insects that survived in each case probably became stupefied before the introduction of the fumigant.

The differences in kill obtained in table 4 are explained by an examination of sorption measurements on active and inactive rice weevils. The method followed in these sorption determinations was the same as that already described by Carpenter & Moore (1938), except that the insect chamber was evacuated to 60 mm. air pressure instead of to 1 or 2 mm. This was necessary in order to obtain results with active insects. In measuring the sorption on inactive insects at 60 mm. air pressure, the rice weevils were stupefied by being allowed to remain at this pressure for three hours before the introduction of hydrocyanic acid. Several experiments were performed at different pressures of hydrocyanic acid; a typical experiment is given in table 5. The results show that the sorption of hydrocyanic acid on active rice weevils is considerably

Table 5.—Sorption of hydrocyanic acid by active and inactive rice weevils. Dosage of HCN = 49 mgs. l.; temperature = 20 degrees C.

Time in Minutes	Inactive Rice Weevils at		Active Rice Weevils at 60 mm.
	1–2 mm.	60 mm.	
2	0.110 mg./gm.	0.118 mg./gm.	0.728 mg./gm.
5	0.160	0.122	0.735
10	0.222	0.153	0.769
15	0.276	0.192	0.827
20	0.314	0.234	0.877
30	0.414	0.314	0.955
40	0.497	0.398	—

greater than that on the inactive form, and that the difference is almost entirely due to the much greater amount sorbed by the active insects during the first two minutes, fig. 3. After this first quick sorption the rate is the same (within experimental error) as that obtained on inactive rice weevils either at 60 mm. or 1–2 mm. air pressure. Similar experiments were made on active and inactive confused flour beetles at 60 mm. air pressure. These experiments showed that the active insects did not sorb any more hydrocyanic acid than inactive insects.

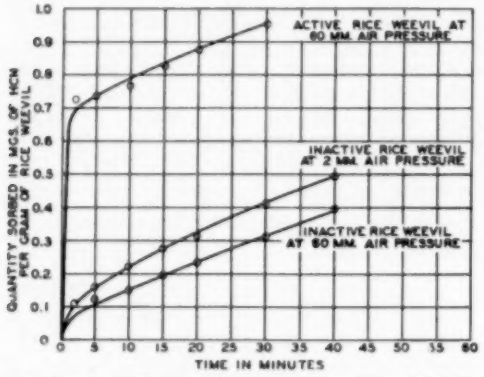
ACTIVE RICE WEEVIL AT 60 MM. AIR PRESSURE
INACTIVE RICE WEEVIL AT 2 MM. AIR PRESSURE
INACTIVE RICE WEEVIL AT 60 MM. AIR PRESSURE
QUANTITY SORBED IN MGS. OF HCN PER GRAM OF RICE WEEVIL
TIME IN MINUTES
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
0 5 10 15 20 25 30 35 40 45 50 55 60

FIG. 3.—Quantities of hydrocyanic acid sorbed by active and inactive rice weevils with time. Concentration of hydrocyanic acid equals 49 mgs./liter.

Evidently some change occurs in the rice weevil when it becomes inactive that does not take place in the confused flour beetle. All of the experimental evidence thus far obtained indicates that hydrocyanic acid is prevented in some manner from penetrating the inactive rice weevil, whereas it is taken up as readily by the inactive as the active confused flour beetle. This is perhaps most clearly shown by the different rates of sorption observed for active and inactive rice weevils as compared with nearly the same rate for both active and inactive confused flour beetles. These differences between rice weevils and confused flour beetles can be explained by assuming that the tracheae of rice weevils are closed when they are inactive. Although this appears to be the most plausible explanation, it may be that the hydrocyanic acid is prevented from penetrating the insect by some other reaction of the rice weevil such as a movement of the elytra. It has been impossible to determine how hydrocyanic acid penetrates the body of the insect.

Experiments have also been made to determine whether or not the presence of nitrogen or of oxygen has an influence upon the kill of active and inactive rice weevils when fumigated with hydrocyanic acid, table 6. Runs 1–3 with active insects show that it is necessary to increase the dosage of hydrocyanic acid about three times when 600 mm. of nitrogen has been added to the system in order to obtain a kill comparable to that obtained without added nitrogen. The effect of nitrogen on

Table 6.—Effect of oxygen and nitrogen on rice weevils fumigated with hydrocyanic acid. Temperature of fumigation = 25 degrees C.

Run	Condition of Insect†	Air Pressure in mm. of Hg.	Pressure in mm. of Added N_2 or O_2	Total Pressure in mm.*	Dosage of HCN in mg./l.	Exposure (Mins.)	Percentage Kill
1	Active	100	—	100	7.3	10	89.6§
2	Active	100	600 of N_2	700	7.3	10	26.8§
3	Active	100	600 of N_2	700	21.7	10	84.6§
4	Active	640	—	640	190.2	10	84.5
5	Active	60	—	60	3.8	10	84.1
6	Active	20	44 of O_2	64	3.8	10	39.3
7	Active	1–2	60 of O_2	62	3.8	10	18.9
8	Inactive	1–2	—	1–2	40.5	60	54.9‡
9	Inactive	1–2	600 of N_2	602	40.5	60	24.9‡
10	Inactive	1–2	—	1–2	55.4	60	99.6§
11	Inactive	1–2	600 of N_2	602	55.4	60	88.7§
12	Inactive	1–2	—	1–2	69.6	60	100.0§
13	Inactive	1–2	600 of N_2	602	69.5	60	98.7§

* Excluding pressure due to hydrocyanic acid.
§ Runs 1–3 and 10–13, inclusive, are the average of two determinations.
† At time of introduction of hydrocyanic acid.
‡ Runs 8 and 9 are the average of three determinations.

Table 7.—Effect of air pressure on different species of insects fumigated with hydrocyanic acid, 10-minute exposure at 25 degrees C.

SPECIES OF INSECT	DOSAGE OF HCN IN MG./L.	PERCENTAGE KILL AT AIR PRESSURE OF			
		2 mm.	30 mm.	60 mm.	90 mm.
Cigarette beetle†	1.06	51.9 (5)	73.8 (3)	74.4 (4)	66.8 (3)
Cigarette beetle	1.52	81.1 (2)	98.1	93.0	85.6
Cigarette beetle	0.36‡	69.6 (3)	79.1 (3)	58.8 (2)	56.9 (2)
Granary weevil	7.19	6.1	89.3	78.4	—
Flat grain beetle	1.45	10.3	46.3	50.7	—
Saw-toothed grain beetle	0.46	30.0	—	79.6	—
Lesser grain borer	1.45	78.0	77.1	74.5	—

† Experiments with cigarette beetles were run at 20° C.
‡ One hour exposure.

inactive insects is shown in runs 8–13. It is interesting to note in this connection that a slightly greater sorption was obtained with inactive rice weevils at 1–2 mm. air pressure as compared with inactive insects at 60 mm. air pressure, table 5. No comparison of the nitrogen effect on active and inactive rice weevils can be made because the experiments were run with different dosages, exposures and total gas pressure. The effect of oxygen is shown in runs 3–7. Runs 3 and 4 show that it is necessary to increase the dosage of hydrocyanic acid about nine times in order to obtain the same kill when the oxygen pressure is increased from about 21 mm. to about 134 mm.

RESULTS WITH OTHER SPECIES OF INSECTS.—The results listed in table 7 show the effect of air pressures on several different species of insects. The numbers in parentheses immediately following the percentage kills again indicate the number of runs from which the average was taken in cases where more than one experiment was made. Since only a very few runs have been made with granary weevils, *Sitophilus granarius* (L.), flat grain beetles, *Laemophloeus minutus* Oliv., saw-toothed grain beetles, *Oryzaephilus surinamensis* (L.), and lesser grain borers, *Rhizopertha dominica* F., the results must be regarded as preliminary indications of the effect of air pressure rather than an absolute proof. The effect obtained with cigarette or tobacco beetles, *Lasioderma serricorne* (F.), is similar to that on rice weevils in that the poorest kill is obtained at 2 mm. air pressure; the differences between 2 mm. and 60 mm. air pressure, however, are not nearly so great for tobacco beetles.

The results indicate that granary weevils, flat grain beetles and saw-toothed grain beetles are also similar to rice weevils. There appears to be no effect of air pressure on the lesser grain borer up to pressures of 60 mm.

SUMMARY.—An apparatus has been described which may be used either for the determination of sorption or the toxicities of different vapors or gases on insects at air pressures from complete vacuum to atmospheric pressure.

A study has been made of the susceptibility of several different insects to hydrocyanic acid at different air pressures. The best kills of confused flour beetles were obtained with inactive insects at 1–2 mm. air pressure, whereas the best kills of rice weevils, granary weevils, flat grain beetles, tobacco beetles, and saw-toothed grain beetles were obtained at 30–60 mm., where the insects were active. The lesser grain borer showed no difference in kill between 2 mm. and 60 mm. air pressure. The percentage kills decreased in all cases studied as the air pressure increased from about 60 mm. to atmospheric pressure.

The reduction in kill due to the presence of air in the fumigation chamber has been shown to be due to nitrogen as well as oxygen.

Sorption experiments have shown that active rice weevils take up much larger quantities of hydrocyanic acid than inactive rice weevils, whereas no difference was found between active and inactive confused flour beetles.

It appears that some insects (typified by the rice weevil) are able to prevent the penetration of hydrocyanic acid to some extent when they become inactive, whereas other insects (typified by the confused flour beetle) are not able to accomplish this result.—4-29-38.

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Tennessee Valley Mosquito Collections[1]

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Although extensive records of mosquito collections are obtainable for most of the northern part of the United States, and a great deal of collecting has been done in the far South, especially Florida, no great amount of work has been done in the area between these two sections. In this area between, one might expect to find both northern and southern forms, and it is not improbable that previously unreported species might occur.

In view of the fact that few records are available for the region, this paper dealing with the mosquito collections in the Tennessee Valley during the years 1934, 1935 and 1936 has been prepared.

The portion of the Tennessee Valley where most of the collections were made comprises the areas surrounding Norris,[2] Guntersville, Wheeler, Wilson and Pickwick Landing Dams;[3] the last four named being in the area referred to in this paper as the Muscle Shoals Area. Some collections are also mentioned which were made in the Great Smoky Mountains and at Reelfoot Lake. The area lies between 34° 40′ and 36° 35′ north latitude and ranges in altitude from a stream bed elevation of 350 feet at Pickwick Landing Dam to a stream bed elevation of 1050 feet at the proposed Cumberland Gap Dam Site near Arthur, Tenn. Although most of the collecting[4] was done in the reservoir area within the limits of elevation listed above, the additional height of the mountains and foothills must not be forgotten. Some of these reach an altitude of more than 6000 feet.

A varied environment is offered mosquitoes in the physical and chemical nature of the waters, as there are swift streams, sluggish streams, lime sink ponds, sloughs, overflow ponds, rock pools, varied artificial containers and impounded waters varying in size from mountain ponds to tremendous reservoirs formed by the various dams and by an even greater variation found in the aquatic vegetation of the different sections.

COLLECTING AND REARING METHODS.—The collecting methods used were essentially the same as have been described by other collectors. An ordinary dipper was used for the majority of the larval collections. This was supplemented at intervals by a tea strainer and, when collecting was done in almost inaccessible places such as tree holes, by a long piece of glass tubing with a rubber bulb attached. A flashlight, chloroform tube, "poofer" and an aspirator were used in collecting adults.

In addition to the numerous barns used for *Anopheles quadrimaculatus* Say catching stations in the Muscle Shoals Area, two experimental animal traps were constructed in anticipation that they might later be used to check *A. quadrimaculatus* production in areas where no barns were available.

These traps were small sheds just large enough to accommodate one or two persons while they collected mosquitoes inside. A tight fitting door was provided, the sides were almost entirely screened except for horizontal apertures and the re-

[1] A contribution from the Health Section of the Tennessee Valley Authority.

[2] Work in the Norris Area under the supervision of W. G. Stromquist, Sanitary Engineer.

[3] Work in the Muscle Shoals Area under the supervision of R. B. Watson, M.D.

[4] Help in collecting was received from Dr. J. B. Lackey, J. S. Wiley, C. W. Kruse, Noah Aston, C. C. Kiker and C. D. Fairer. The identifications were confirmed by Dr. W. V. King and G. H. Bradley of the U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine; *Orthopodomyia alba* Baker was also confirmed by Dr. Alan Stone of the U. S. National Museum.

mainder of the building was tightly boarded.

The horizontal apertures were inserted at the sides in an attempt to copy the funnel in a fly trap. Two boards were placed in such a manner that their inner edges were much closer to each other than their outer edges, thus forming a narrow slit through which a mosquito could enter, but could escape only with great difficulty.

A calf or other small animal was kept in the shed overnight, and the mosquitoes which were trapped inside were collected the next morning.

Rearing was carried on to obtain adults and to check the larval identifications. This was done in any convenient jar with no food added except water from the original environment. All the lots of mosquitoes were numbered to correspond to the field notes and, if it was desirous to associate the adult when it emerged with the cast larval skin, the rearing was accomplished in individual tubes marked with the lot number, and a serial number was prefixed at the time of emergence.

COLLECTIONS.—Brief notes on each species collected are given as follows:

Anopheles punctipennis (Say).—This species occurs throughout the area. More abundant early and late in the summer than during the hot weather. Most abundant in the Norris Reservoir spring fed streams prior to impoundage. Breeds in swift streams, if not too swift for a fringe of vegetation. Adults prefer to rest during the day under rock ledges, bridges or hollow trees during the warmer months and in barns and sheds during the late fall and early spring. Larvae found as late as December 18 in Norris Reservoir; appearing in spring about April 15. The earliest record was March 31 at Wilson Dam, Ala., but there is evidence of overwintering in the larval stages at the bottoms of ponds.

Anopheles crucians Wiedemann.—Adult females were taken in small numbers from the catching stations in Pickwick, Wheeler and Wilson Reservoirs. Adult males were observed resting in well shaded driftwood. The larvae prefer slightly acid water. Larvae and adults occur throughoug the summer.

Anopheles quadrimaculatus Say.—This mosquito was found in the entire area studied. It was found only near Andrew Jackson Lake in the Norris Dam region prior to impoundage, but was found near Norris Lake on June 20 after the starting of impoundage in May. Substantial collections were made during the rest of the summer, and the abundance of this species was checked later only by control measures.

Anopheles barberi Coquillett.—One female was collected at Norris, Tenn., from a log barn late in June. Larvae and adults were collected during June, July and August from a tree hole in a sweet gum near Wilson Dam, Ala.

Anopheles walkeri Theobald.—The only specimens taken within the region were sent to me by H. A. Johnson from Reelfoot Lake in northwestern Tennessee. They were collected early in September.

Aedes dupreei (Coquillett).—A single larva of this species was taken during September from a grassy pond in the Pickwick Reservoir before impoundage. No more larvae were found and no adults were taken, although the area was searched carefully.

Aedes hirsuteron (Theobald).One adult specimen was taken, while biting, in an office at Wilson Dam. Other adults were taken at intervals during May and early June, when biting, near Florence and Huntsville, Ala. No larvae of this species were obtained.

Aedes thibaulti Dyar and Knab.—This species was fairly abundant in restricted wooded areas around Wilson Dam and Huntsville, Ala., from March to July. Larvae were found in holes at the bases of trees and stumps. The adults rest in the hollow stumps and trees near the breeding places and come out to bite if a human being remains long in the vicinity. Not taken elsewhere.

Aedes canadensis (Theobald).—*Aedes canadensis* was found quite generally throughout the Muscle Shoals Area. Specimens were first found on February 28 and were last observed, but at that time quite abundant, on March 31 in the vicinity of Wilson Dam. Only one group of larvae was found near the Norris Reservoir and that on April 22. The larvae had all emerged when this pool was examined one week later and did not appear again, thus indicating a one brooded species. The larvae prefer small wooded pools with a bottom of dead leaves, but they have been taken from red silty water along roadsides in Alabama. The adults bite readily

if a person enters the woods where they are abundant.

Aedes atropalpus (Coquillett).—Collected by W. M. Pritchard at Kinzel Springs, Tenn., in May from a rocky pool. Specimens were also obtained from an abandoned septic tank near Knoxville. No adults of this species were found.

Aedes triseriatus (Say).—Specimens of *Aedes triseriatus* were collected from tree holes throughout the area at almost any time during the summer. They were the most abundant of the tree hole breeders. The adults bite readily.

Aedes vexans (Meigen).—This species was collected once in the Norris Reservoir and many times in the Muscle Shoals Area. It is not particular in its choice of breeding places; it has been found in roadside ditches, septic tanks, ponds in open fields, ruts, furnace pits and overflow pools. It was collected on March 30 from Weakly Pond near Florence, Ala. Although this pond had been examined periodically for nearly two years it had produced no mosquitoes up to this time. The adults were taken in offices at Wilson Dam and were collected on numerous occasions from light and animal traps.

Aedes aegypti (Linnaeus).—This species occurred over the entire area and was collected in mosquito stations in Pickwick, Wilson, Wheeler and Guntersville Reservoirs. Other records are from houses in Florence and Wilson Dam, Alabama and one record of a collection on February 19 from potted plants in an automobile show room in Knoxville, Tennessee. Cans and rubbish were not allowed to accumulate in quantities so they were not very numerous.

Culex peccator Dyar and Knab.—One larva of this species was collected from a pond in the Pickwick Reservoir early in September. No other larva or adult was found.

Culex inhibitator Dyar and Knab.—This species was taken in considerable number throughout the area examined. It seemed to prefer grassy pools similar to those frequented by *Anopheles* and was often found with them. Specimens were collected numerous times among the algae formed below springs. They occur throughout the summer.

Culex salinarius Coquillett.—This species was often collected from grassy pools throughout the summer and from all the areas except Norris, where it also probably occurs. Records from the live trap at Decatur, Ala., show a great abundance of this species in that area.

Culex restuans Theobald.—This mosquito was collected from ditches, hollow stumps, tree holes, septic tanks, old boats, stagnant pools, rain barrels, water troughs, impounded water, cattle tracks, basements, old tires and temporary puddles. It often occurred in great numbers so that hundreds could be obtained from a single dip and was collected more than any species except *Anopheles*. The adults were often taken in the catching stations in all the areas.

Culex quinquefasciatus Say.—The southern house mosquito was abundant in all areas except the Norris Area, but not as abundant in the places where collections were made as *C. restuans*. No deviation from described habits was noted.

Culex pipiens Linnaeus.—The northern house mosquito was found only in the Norris Area. Here specimens were taken as larvae from rain barrels, cattle troughs and stagnant pools and as adults from numerous stations and from the basements of cattle barns. The species, identified by the male genitalia, was found at Concord, Tenn., (34° 53′ north latitude).

Culex apicalis Adams.—This is a common species throughout the area studied, and, although usually found in grass and algae filled spring branches and ponds, upon one occasion specimens were found breeding in an old septic tank in great numbers. The presence of green algae in the water causes this species to take on a green color. This characteristic was also noticed in the *Anopheles*, *Uranotaenia sapphirina* and *Culex inhibitator*.

Theobaldia melanura (Coquillett).—Taken only in the Wilson Dam Area. One adult female was taken in the administration building on March 17. Larvae were taken near Wilson Dam at intervals during the months of May and June. They were breeding in water at the bases of trees and stumps and seemed to prefer places chosen by *Aedes thibaulti*. No great numbers found at any one time.

Theobaldia inornata (Williston).—*Theobaldia inornata* was collected in great numbers, between March 30 and April 8, from a wet weather pond in an open cow pasture. A few specimens were also collected from a ditch where *Culex apicalis*,

C. salinarius, *Anopheles punctipennis* and *C. restuans* were breeding.

Psorophora howardii Coquillett.—Representatives of this species occurred throughout the area, but only a few were taken near Norris. This is a viscious biter. On account of its cannibalistic habits each larva must be isolated if adults are to be reared. Occurs throughout the summer.

Psorophora ciliata (Fabricius).—This species was not found in the Norris Area, but was more abundant in the other areas than *P. howardii*. Collections were made all summer and several times from the live-calf trap.

Psorodophora ferox (Humboldt).—The adults were very abundant in certain places around Wilson Dam, but they were not taken at Norris. They are quite annoying during the daytime in woods near ponds. Adults were also taken in live-calf traps.

Psorophora varipes (Coquillett).—One collection of adults only was made. This was in a heavy and recently drained tupelo swamp near Guntersville, Ala. They were collected, while biting, on July 29. *P. ferox*, *P. cyanescens* and *Aedes triseriatus* were also present and biting at the same time.

Psorophora cyanescens (Coquillett).—This species was probably the most abundant *Psorophora* in the Muscle Shoals Area, although not taken at Norris. On numerous occasions it was taken, while biting, in the woods. On one occasion, a considerable number was collected by G. E. Smith, in a parked automobile, by lowering the window glasses for short intervals and permitting a few specimens to enter. Larvae were collected from temporary pools from May to September.

Psorophora discolor (Coquillett).—Larvae of this species were collected from the Norris Area from July 10 to October 18. A collection of larvae was made at Huntsville, Ala., during September. They were found breeding in a grassy and somewhat polluted pond, a pool under a corner of a barn and in a shallow automobile rut. The larvae in the rut remained motionless on their backs, seemingly anchored to the bottom by their breathing tubes; they were easily collected with a tea strainer. Other collections were obtained while dipping for other species. No adults were obtained but those reared.

Psorophora columbiae (Dyar and Knab).—Collections of larvae and adults of this species where in all areas. This species was found breeding mostly in temporary rain pools, in ruts or low places of a temporary nature. The adults were obtained, while biting, near these places or from live-calf traps.

Psorophora signipennis (Coquillett).—One adult female was obtained, but was lost in the mail when sent for confirmation. Identification doubtful.

Mansonia perturbans (Walker).—This mosquito was taken at rare intervals at one of the Wilson Dam mosquito stations and quite regularly at one of the live traps located near Decatur, Ala. Both the mosquito station and the calf trap were near rather extensive areas of cat-tails. No attempt was made to collect the larvae by McNeel's method (McNeel 1934).

Uranotaenia sapphirina (Osten-Sacken).—*Uranotaenia sapphirina* was collected from grassy pools near Concord and Tazewell, Tenn., and from numerous places in the Muscle Shoals Area. Adults were not taken in any of the stations, although these stations were close to breeding areas.

Orthopodomyia alba Baker.—From June 25 to August 4 *Orthopodomyia alba*[5] larvae were taken from a sweet gum tree hole near Wilson Dam, Ala. Specimens were present with *O. signifera*, *Aedes triseriatus* and *Anopheles barberi*.

No others of this species were found in spite of the numerous tree hole collections made during this period in various points throughout the Tennessee Valley Authority's area in northern Alabama and Mississippi. No adults were obtained except six which were reared.

Orthopodomyia signifera (Coquillett).—Collected from one tree hole near Coal Creek, Tenn., in the Norris Area and from several tree holes in the Muscle Shoals Area. Specimens were also furnished by H. A. Johnson from Reelfoot Lake, Tenn. They are often very abundant in tree holes. One adult was taken from a house in Wilson Dam, but it had made no attempt to bite.

Megarhinus septentrionalis Dyar and Knab.—This is probably the largest and most striking mosquito that was collected. Records were obtained from a rain

[5] V. I. Miles, U. S. Public Health Service helped with the first collection.

barrel near Tazewell, Tenn., where they were found with *Culex pipiens* and *C. restuans;* also from Coal Creek, Tenn., where they were breeding with *Orthopodomyia signifera* in a stump hole. One adult was caught in daylight near the stump in which the larvae were found. The particular buzz they make while flying is high pitched and distinctly characteristic. No specimens were found in the other areas, but doubtless the species occurs there.

SUMMARY.—This paper gives an account of mosquito collections in an area seldom visited by collectors and gives data on types of breeding places and periods through which the mosquitoes occurred in cases where records on a species are vague and inadequate.

A definite record of *Culex pipiens*, confirmed from larvae and male genitalia, is obtained from a region farther south than any previous reports known to the author. —2-10-38.

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Relative Toxicities to Insects of Acid Lead Arsenate, Calcium Arsenate and Magnesium Arsenate

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For more than half a century, arsenical insecticides have been used on plants for the control of chewing insects. During the early part of this period the main arsenicals used for this purpose were Paris green, London purple, Scheele's green; to a lesser extent other arsenates and arsenites, and even white arsenic were used. Most of these materials were effective against various insect pests but were also toxic to the plants to which they were applied. It, therefore, became necessary to study the effect of various arsenicals on plants; as a result, it was found that plant injury was due to soluble arsenic.

Attention was then turned to the use of the more insoluble arsenicals in the hope that some of these materials which were not injurious to plants would be highly toxic to insects. Acid lead arsenate, calcium arsenate and magnesium arsenate most nearly met these requirements, and are, with the exception of Paris green, the only arsenicals extensively used today for the control of chewing insects on plants. For many insects these insoluble arsenicals were found to be as toxic as, or only slightly less toxic than, the much more soluble arsenicals formerly used. Since only soluble materials can pass through the cell walls lining the digestive tract, it is obvious that these slightly soluble arsenicals must become more soluble within the alimentary tract of insects before poisoning can occur.

Evidence that an increase in solubility actually occurs was presented by Cook & McIndoo (1924). Additional evidence was furnished by Fulmek (1929) who found that the relative solubilities of some arsenicals in NaOH-glycine buffer mixtures, having a pH 9.0, was indicative of the relative toxicity of these materials to one species of beetle and three species of caterpillars. It would appear, therefore, that the effectiveness of these poisons to an insect would be determined largely by the effect of the insect's digestive juices upon the solubility of the poison. The research herein reported approached the problem of relative toxicity from this standpoint and consisted of a study of the digestive secretions of insects, the determination of the effect of hydrogen ions and phosphate ions on the solubility of acid lead, calcium and magnesium arsenates, and the determination of the relative toxicity of these poisons to various insects.

DIGESTIVE TRACT OF INSECTS IN RELATION TO TOXICITY OF ARSENICAL INSECTICIDES.—The main factors in connection

* Early publication of this paper has been secured by payment of the printing charge.

with the digestive tract which would be expected to influence toxicity are the structure of the digestive tract and the nature of the digestive juices, with special reference to the acidity and the anions and cations present. The previous knowledge concerning these factors will be briefly reviewed and the results from the present investigation given.

STRUCTURE AND FUNCTIONS OF THE ALIMENTARY TRACT OF INSECTS.—The fore-gut of insects is lined with a relatively thick chitinous intima and serves mainly as a temporary storehouse for the food. While it secretes no digestive enzymes, some of the digestive fluids pass from the mid-gut into the fore-gut, and the preliminary stages of digestion of the food take place there. The evidence available from the work of Abbott (1926), Biedermann (1898) and Basch (1858) indicate that little or no absorption of water-soluble compounds occurs in the fore-gut due to the thickness of the chitinous lining of this section of the gut. However, considerable evidence is presented by Abbott and Biedermann indicating that the absorption of fats and fat-soluble materials can take place in the fore-gut and that the chitinous lining is permeable to fats.

The mid-gut has little or no chitinous lining, but is composed largely of secretory cells whose function is to manufacture and secrete the digestive juices. The mid-gut absorbs most of the digested material, which must pass through a peritrophic membrane surrounding the food.

The hind-gut has a thin, chitinous lining through which water, water-soluble materials and fats are absorbed very slowly. Its main functions would appear to be, first, the conservation of water for the organism by its removal from the indigestible materials and, second, the elimination from the organism of waste materials.

Since the arsenical poisons are water-soluble rather than fat-soluble, it is evident from the above discussion that the mid-gut is the principal region for the absorption of these poisons, with the probability that some is absorbed in the hind-gut. The work of O'Kane & Glover (1935) would indicate that some of the soluble arsenic might also pass through the heavy chitinous lining of the fore-gut, as they were able to demonstrate penetration of soluble arsenic through the chitinous prothorax of cockroaches. Certainly, however, the absorption occurring in the fore-gut would be of less importance than that occurring in the mid-gut.

ACIDITY OF THE DIGESTIVE TRACT OF INSECTS.—The acidity of the digestive tract of insects has been of interest to entomologists since early in the nineteenth century. Marcel de Serres (1813) reported finding the mid-gut secretions of Orthoptera alkaline, Basch (1858) reported the mid-gut secretions of the oriental roach neutral or alkaline and Frenzel (1882) reported these secretions alkaline in the mealworm.

Plateau (1873), after working upon *Blatta americana*, Acrididae and Locustidae, stated that, in general, carnivorous and omnivorous insects with chewing mouthparts have a slightly acid digestive juice, while plant feeding insects always have an alkaline digestive juice. However, Swingle (1931b), reporting work upon 41 species of insects, concluded, "No satisfactory correlation can be made from these results between the acidity and the type of food eaten by the insect. In general it might be said that the mid-gut tends to be more acid than the fore- and hind-guts in carnivorous insects, while it is more alkaline in phytophagous species, but this is not always the case. Samples from larvae seem to be much more alkaline than samples from adults of the same species, especially among the Coleoptera."

The range of acidities found in the mid-gut contents of species in the various orders of insects was compiled from the

Table 1.—The range of acidity in the mid-gut contents of insects in the various orders.

ORDER	OBSERVER	NUMBER OF SPECIES	RANGE IN pH OF MID-GUT CONTENTS	
			Minimum	Maximum
Orthoptera	Bodine (1925), Swingle (1931b), Wigglesworth (1927)	25	5.6	7.6
Neuroptera	Swingle (1931 b)	1	6.4	—
Odonata	Shinoda (1930b), Swingle (1931b)	2	5.4	7.2
Hemiptera	Swingle (1931b)	2	5.5	7.2
Coleoptera	Shinoda (1930b), Swingle (1930a), Swingle (1931b)	24	5.5	7.2
Lepidoptera	Shinoda (1930a), Swingle (1928), Swingle (1931b)	5	7.2	10.3
Trichoptera	Shinoda (1930b)	1	—	9.2
Diptera	Swingle 1928	4	6.8	8.0
Hymenoptera	Swingle (1931b), Tietz (1924)	5	6.2	7.3

published records of various workers and recorded in table 1. From these data it appears that in many orders the digestive juices range from acid to alkaline, but insufficient records are available to draw any conclusions concerning the majority of orders. All species of Lepidoptera studied had alkaline digestive fluids.

While wide variation has been found to exist in the acidity of the mid-gut contents of different species within an order, much less variation has been found to exist within a species. Wigglesworth (1927) and others have found considerable variation in the acidity of the crop, depending on the type of food eaten and the stage of digestion of the ingested food, but much less variation in the reaction of the mid-gut, as would be expected from the fact that the digestive juices are secreted there. Swingle (1931a) found that the digestive fluids of Japanese beetle larvae were buffered against acids and that the ingestion by the larvae of soils varying in pH from 3.47 to 6.45 had no influence on the acidity of the digestive tract.

METHOD OF DETERMINING ACIDITY OF DIGESTIVE JUICES.—It is apparent from the above discussion that the acidity of the digestive juices must be determined for each species of insect under investigation. In the present investigation freshly fed insects were used in order to secure copious secretions of digestive fluids. These insects were anaesthetized and the digestive tracts removed. Each digestive tract was washed with distilled water. A sample of the contents was removed from the mid-gut by pricking the wall with a scalpel and collecting the juice with a pipette. The pH was determined immediately by using the quinhydrone electrode for fluids having an acid reaction and the hydrogen electrode for those with an alkaline reaction. Separate determinations were made on fifteen individuals of each species and the results averaged.

RESULTS OF TESTS ON DIGESTIVE JUICES.—The results of these tests for the nine species of insects used are given in table 2. The digestive juices of these insects varied in acidity from pH 5.9 to 9.6. The three species of lepidopterous larvae and the adult click beetle had alkaline digestive juices, while five species of leaf feeding beetles had acid digestive secretions. Apparently, therefore, Plateau's contention that all leaf feeding insects have alkaline digestive juices was based on insufficient evidence.

Table 2.—Hydrogen-ion concentrations of the digestive secretions of various insects and the principal anions and cations present.

INSECT	COMMON NAME	STAGE	pH OF MID-GUT†	ANIONS PRESENT	CATIONS PRESENT
Diabrotica balteata Lec.	Banded cucumber beetle	Adults	5.9	PO_4, CO_3	K, Na, Ca, Mg
Epilachna varivestis Muls.	Mexican bean beetle	Adults	6.0	PO_4, NO_3	K, Na, Ca, Mg
Epilachna varivestis	Mexican bean beetle	Larvae	6.0	PO_4, CO_3	K, Na, Ca, Mg
Leptinotarsa decimlineata (Say)	Colorado potato beetle	Adults	6.4	PO_4, CO_3	K, Na, Ca, Mg
Epicauta vittata F.	Striped blister beetle	Adults	6.6	PO_4	K, Na, Ca
Anthonomus grandis Boh.	Boll weevil	Adults	6.5	*	*
Monocrepidius lividus (De G.)	Click beetle	Adults	7.3	PO_4	K, Ca, Na
Heliothis obsoleta (F.)	Corn ear worm	Larvae	8.0	PO_4	K, Ca, Na
Datana integerrima G. & R.	Walnut caterpillar	Larvae	9.5	PO_4, NO_3, CO_3	K, Na, Ca, Mg
Protoparce sexta (Johan.)	Tomato worm	Larvae	9.6	PO_4, Cl, NO_3	K, Na, Ca

* Insufficient material present for analysis.
† Average from 15 separate determinations.

ANIONS AND CATIONS IN THE DIGESTIVE JUICES OF INSECTS.—Little work has been done on the anions and cations in the digestive secretions responsible for the pH of the digestive fluids. Frenzel (1882) found magnesium and phosphate ions present in the digestive secretions of the yellow mealworm, *Tenebrio molitor* L., and also in that of various Coleoptera, Orthoptera, Neuroptera and Homoptera. He concluded that magnesium phosphate was present in the digestive secretions of all Hexapods and possibly in those of all Arthropods. Vángel (1886) reported finding magnesium phosphate in the digestive

secretion of *Hydrophilus piceus* L. Kirkland & Smith (1897) found potassium phosphate in the digestive tract of 27 species of lepidopterous larvae. Biedermann (1898) reported that the alkalinity of the digestive juices of the yellow mealworm, *T. molitor* L., was due to an acid phosphate of sodium or potassium. Swingle (1930b) reported finding the following cations and anions in the digestive juices of Japanese beetle larvae: Al, Fe, Ca, Mg, K, Na, NH_4, CO_3, Cl, NO_2 PO_4. He also reported (1931a) that the digestive secretions of the mid-gut had a pH 9.5, and possessed considerable buffering power against acids. It would appear, therefore, that the pH and buffering power of the digestive juices of this insect were due to the phosphate of a strong base (either Mg, Na, K or NH_4).

The evidence available would seem to indicate that the digestive secretions of most insects contain the phosphate ion combined with one or more bases. In order to secure definite information on the insects used in these tests, analyses were made of the mid-gut secretions of a number of economically important insects.

METHODS FOR DETERMINING ANIONS AND CATIONS PRESENT.—For the determination of the anions and cations present in the digestive juices of each species, from 10 to 100 specimens, depending on their size, were dissected and the digestive juice removed as described above. Tests for ammonia were made on the fresh material. The remainder of the juice was dried, ashed and then analyzed by the microchemical methods of Hinrichs (1904) and Chamot (1921). These results were checked by standard qualitative analytical methods where sufficient material was available. The presence of the phosphate ion was further checked by allowing fresh juice to evaporate at room temperature, extracting with distilled water and testing the extract by the Benedict-Theis (1934) colorimetric method. Where necessary, the samples were concentrated by evaporation sufficiently for the principal inorganic materials present to give a test. It is evident, therefore, that the anions and cations reported were merely those most abundant.

RESULTS OF TESTS FOR ANIONS AND CATIONS.—The results of these analyses are given in table 2. Phosphate was the only anion found in the mid-gut of all insects tested. These results and those of other workers cited above would appear to justify the statement that phosphoric acid is a component of the digestive juice of most, if not all, insects. The other acids reported were present in traces only.

Potassium was the only cation found abundant in any of the species tested, but it was present in very small amounts in mid-guts with an acid reaction. Small amounts of magnesium, calcium and sodium were found in various species. The evidence at hand does not justify drawing any conclusions as to the cations with which the phosphate ion was combined. From the variations in the acidity of the mid-guts of various insects, it would appear probable that this differs with different species.

FACTORS AFFECTING RATE OF SOLUTION OF ARSENIC.—In order that the action of the arsenical insecticides might be more fully understood, it was important to determine the factors affecting the rate of solution of the arsenic. Since the pH of the solution is known to affect the solubilities of relatively insoluble compounds, it was considered advisable to determine the effect of solutions of various hydrogen ion concentrations on the arsenical insecticides. As the phosphate ion appeared to be a component of the digestive juices of insects, it also appeared important to determine the effect of this anion on these same poisons.

In these studies and in those succeeding, commercial grades of three arsenates were used. They were analyzed by the official methods (Association of Official Agricultural Chemists 1924) and found to contain the following amounts of arsenic, expressed as As_2O_5:

Acid lead arsenate—31.03 per cent total, and 0.18 per cent water-soluble arsenic

Calcium arsenate—42.7 per cent total and 0.10 per cent water-soluble arsenic

Magnesium arsenate—33.04 per cent total and 0.12 per cent water-soluble arsenic

These analyses are typical of good commercial grades of the above arsenates.

METHODS FOR DETERMINING RATE OF SOLUTION OF ARSENIC.—Buffer solutions were made with acetic acid, potassium acetate and potassium hydroxide for the pH range 2.0 to 10.0 at intervals of 1.0 pH. The pH values of the solutions were

checked with the hydrogen electrode before the addition of the arsenicals and subsequently by the quinhydrone electrode for the values below 8.0 and by the colorimetric method for higher pH values. This change in method was necessary due to the "poisoning" of the hydrogen electrode by the soluble arsenic. Two grams of acid lead arsenate was added to 1 liter of buffer solution and the mixture incubated for a total of 50 hours in a water bath at 32 ± 0.1 degree C. Calcium and magnesium arsenates were used in amounts equivalent in arsenic content to the above amount of acid lead arsenate. Since the acetate-KOH solutions were poor buffers, their reactions were checked hourly for the first 10 hours and acid or alkali was added as needed to maintain the proper pH value. At intervals of 1, 2, 5, 10, 25 and 50 hours the flasks were shaken and 100 ml. aliquots removed for analysis. These aliquots were immediately filtered and analyzed for soluble arsenic by the official methods (Association of Official Agricultural Chemists 1924).

Since phosphates were found to be present in the digestive tracts of the insects used in this investigation, a second series of buffer solutions was made up using K_2HPO_4, H_3PO_4 and KOH. The arsenical insecticides were added and their rates of decomposition measured as above.

RESULTS OF ACID LEAD ARSENATE TESTS.—The effect of acetate-KOH buffers on acid lead arsenate is given in table 3. The arsenic in acid lead arsenate was slightly soluble at pH 2.0, relatively insoluble at pH 3.0 to 5.0, and the solubility increased with increase in alkalinity from pH 6.0 to 10.0.

The effect of a series of phosphate-KOH buffers on acid lead arsenate is given in table 4. It is apparent that the phosphate ion was without effect on the solubility in the acid range pH 2.0 to 5.0, but its presence increased the amount of soluble arsenic in the range pH 6.0 to 10.0. It would appear, therefore, that in insects with an alkaline digestive fluid the presence of phosphates in this fluid should increase the toxicity of acid lead arsenate.

Table 3.—Effect of hydrogen-ion concentration on the solubility of arsenic in acid lead arsenate.*

pH	Soluble Arsenic as As_2O_5. Milligrams Per Liter					
	1 Hour	2 Hours	5 Hours	10 Hours	25 Hours	50 Hours
1.93	33	33	36	36	37	38
3.06	33	32	32	35	36	37
4.01	24	29	29	31	30	30
5.05	6	15	15	17	14	14
6.20	11	14	21	33	32	32
7.00	10	12	21	36	32	46
8.00	10	17	36	76	122	167
8.98	18	28	83	148	182	207
10.00	29	41	143	162	189	207

* 2.0 grams $PbHAsO_4$ used per liter

Table 4.—Soluble arsenic formed by the decomposition of acid lead arsenate* in phosphate buffer solutions.

pH of Solution	Soluble Arsenic as As_2O_5. Milligrams Per Liter.				
	1 Hour	5 Hours	10 Hours	25 Hours	50 Hours
2.0	1	18	18	18	20
3.0	2	8	8	8	8
4.0	4	8	8	8	12
5.0	4	10	10	12	15
6.0	4	16	18	24	30
7.0	6	120	204	300	412
8.0	170	252	300	365	450
9.0	224	275	300	370	452
10.0	252	290	310	365	450

* 2.0 grams $PbHAsO_4$ used per liter

In order properly to interpret the above results, several important questions must be answered. First, were the changes in soluble arsenic reported in table 3 due to changes in the hydrogen ion concentration of the solution or were they due to the changes in the concentration of potassium which accompanied higher alkalinity? Second, to what extent did changes in the concentration of acids, bases or salts in buffer solutions of a given pH influence the amount of soluble arsenic? Third, why did the presence of the phosphate ion increase the soluble arsenic only in the alkaline range?

In order to answer the first question, experiments were set up in which the potassium concentration was varied while the hydrogen ion concentration was constant, and in which the hydrogen ion concentration was varied while the potassium concentration remained constant. The results, given in table 5, indicate that the effect of any given concentration of potassium was dependent on the hydrogen ion concentration of the solution. It would appear, therefore, that the changes in

Table 5.—Effect of potassium, acetate and phosphate concentrations on the solubility of the arsenic in acid-lead arsenate.

No. Grams Per 1000 cc.*			pH Values		Soluble Arsenic as As_2O_5 Milligrams Per Liter			
Acetic Acid	Potassium Hydroxide	Phosphoric Acid	Initial	Final	1 hr.	2 hrs.	5 hrs.	25 hrs.
		0.4978	2.5	3.0	2	4	7	16
	0.1059	0.4978	5.0	5.8	7	7	9	18
	0.1927		11.0	10.7	70	80	95	110
	0.1927	0.9898	5.0	5.5	6	7	9	15
12.2679			2.5	2.7	4	5	6	9
12.2675	9.0240		5.0	5.3	7	8	10	14
	0.5170		11.5	11.5	96	103	113	115
0.7752	0.5170		5.0	5.0	1	1	3	2
2.4490	2.3798		8.0	8.2	56	81	102	128

* One gram $PbHAsO_4$ used per liter.

soluble arsenic reported in table 4 were not due to changes in the concentration of potassium, but were correlated with changes in the concentration of the hydrogen ion.

In order to answer the second question, the acid, base and salt concentrations were varied at pH 5.0 and 8.0. The results are given in table 6. It is apparent from these results that the concentration of the acetate radical in an acid solution influenced the amount of soluble arsenic slightly and in the alkaline solution practically not at all. The concentration of the phosphate radical was without effect in the acid solution, but in an alkaline solution the amount of soluble arsenic increased with increases in the concentration of phosphate until approximately 80 per cent of the arsenic present had been rendered water-soluble. After reaching this point, the amount of soluble arsenic remained the same regardless of the phosphate concentration.

It would appear from these studies that the concentration of acid radicals, bases and salts influenced to a slight extent the amount of arsenic rendered soluble in a buffer solution of a definite hydrogen ion concentration. However, the amount of arsenic in solution appeared to be influenced to a much greater extent by the hydrogen ion concentration. The results given in table 4 and 5 may, therefore, be considered approximately accurate quantitatively for any given hydrogen ion con-

Table 6.—Effect of salt concentration on the solubility of the arsenic in acid lead arsenate* at pH 5.0 and 8.0.

Grams Per 1000 cc.					pH Value		Soluble Arsenic as As_2O_5 Milligrams Per Liter			
CH_3COOK	CH_3COOH	KOH	H_3PO_4	K_2HPO_4	Initial	Final	1 hr.	2 hrs.	5 hrs.	25 hrs.
4.0	0.6589				5.0	5.10	11	4	6	8
4.0		0.0940[a]			8.0	8.20	56	81	112	168
16.0	3.1008				5.0	5.05	11	14	22	25
16.0		0.3507[b]			8.0	8.40	76	87	123	194
32.0	7.0543				5.0	5.00	17	20	28	42
32.0		0.6918[c]			8.0	8.20	76	92	134	185
			1.9180	4.0	5.0	5.10	6	8	8	14
		0.0470[d]		4.0	8.0	8.05	174	207	305	498
			7.5887	16.0	5.0	5.20	11	14	14	17
		0.1448[e]		16.0	8.0	8.05	291	361	479	507
			15.4967	32.0	5.0	5.00	6	8	14	14
		0.2735		32.0	8.0	8.20	375	428	504	507

a—0.1640 g. KOH added during incubation to maintain pH = 8.0.
b—0.1599 g. KOH added during incubation to maintain pH = 8.0.
c—0.1476 g. KOH added during incubation to maintain pH = 8.0.
d—0.0902 g. KOH added during incubation to maintain pH = 8.0.
e—0.0287 g. KOH added during incubation to maintain pH = 8.0.
* Two grams $PbHAsO_4$ used per liter.

centration of an insect's digestive juices.

In answering the third question it appeared logical that the increase in soluble arsenic in the presence of the phosphate ion might be due to precipitation of part of the lead as lead phosphate. Therefore, the effect of hydrogen ion concentration on the solubility of the lead in lead phosphate and in lead arsenate was determined by using acetate-KOH solutions. These lead salts were used at the rate of 1.286 grams Pb per liter (2 grams acid lead arsenate and 1.6946 grams lead phosphate) and incubated at 32 degrees C. for 25 hours. The lead was determined by the Harris method (Wichmann *et al.* 1934) and the results are given in table 7.

Table 7.—Solubility of the lead* in acid lead arsenate and lead phosphate at various hydrogen ion concentrations.

pH of Solution	Milligrams Soluble Pb Per Liter	
	Acid Lead Arsenate	Lead Phosphate
2.0	154	287
3.0	81	84
4.0	78	104
5.0	15	24
6.0	3	3
7.0	2	2
8.0	2	2
9.0	2	2
10.0	2	2

* 1.286 grams Pb used per liter.

These results indicate that moderate concentrations of phosphate in acid solution might not be expected to increase the solubility of the arsenic in acid lead arsenate, due to the solubility of the lead under these conditions. In alkaline solutions, however, the lead in both acid lead arsenate and in lead phosphate was tied up in insoluble form and, therefore, the presence of the phosphate ion under such conditions would be expected to increase the soluble arsenic by tying up part of the lead from acid lead arsenate as an insoluble lead phosphate. Apparently this actually occurs as is indicated by the results given in table 4.

Results of Calcium Arsenate Tests.—The effect of hydrogen ion concentration on the solubility of the arsenic in calcium arsenate is shown by the data in table 8 for the acetate-KOH buffer solutions and in table 9 for the phosphate-KOH buffers. It is apparent that calcium arsenate behaved directly opposite to

Table 8.—Effect of hydrogen ion concentration on the solubility of the arsenic in calcium arsenate.*

pH	Soluble Arsenic as As_2O_5, Milligrams Per Liter After					
	1 Hour	2 Hours	5 Hours	10 Hours	25 Hours	50 Hours
1.93	622	619	619	622	622	623
3.06	619	622	619	622	622	623
4.01	622	622	622	622	622	622
5.05	594	594	602	597	594	597
6.20	339	289	445	430	433	433
7.00	20	28	58	58	58	58
8.00	35	47	62	70	82	85
8.98	34	48	56	67	67	59
10.00	36	53	53	67	70	53

* 1.453 grams calcium arsenate used per liter.

acid lead arsenate, the former being completely soluble in the acid range and much less soluble in the alkaline range. The effect of the phosphate ion on the amount of soluble arsenic produced was to de-

Table 9.—Soluble arsenic formed by the decomposition of calcium arsenate* in phosphate buffer solutions.

pH of Solution†	Soluble Arsenic as As_2O_5 Milligrams Per Liter After				
	1 Hour	5 Hours	10 Hours	25 Hours	50 Hours
2.0	600	610	600	610	615
3.0	450	600	604	616	622
4.0	424	598	600	608	612
5.0	330	470	550	600	615
6.0	66	108	120	124	120
7.0	42	76	108	120	125
8.0	36	78	110	117	120
9.0	33	74	110	118	115
10.0	30	76	112	120	122

* 1.453 grams calcium arsenate per liter. The arsenate analyzed 42.7 per cent As_2O_5.

† The proper pH was maintained by the addition of acetic acid.

crease it slightly in the acid range and increase it slightly in the alkaline range.

Results of Magnesium Arsenate Tests.—The effect of hydrogen ion concentration on the solubility of the arsenic in commercial magnesium arsenate is shown by the data in table 10 for the acetate-KOH buffer solutions and in table 11 for the phosphate-KOH buffers. Magnesium arsenate was apparently similar to calcium arsenate in behavior, but differed in several particulars. At pH 4.0 it was less soluble than calcium arsenate, but at pH 5.0 to 6.0 it was more soluble. In the alkaline range it was much more

insoluble. The presence of the phosphate ion increased the soluble arsenic slightly in the range of pH 6.0 to 10.0.

RELATIVE TOXICITIES OF THE THREE ARSENATES.—The factors brought out in the preceding sections which would be expected to influence the toxicity of the arsenates are briefly as follows: Only that portion of the arsenic which is soluble is toxic to insects; the amount of soluble arsenic formed from acid lead, calcium and magnesium arsenates is dependent on the hydrogen ion concentration of the solution; the amount of soluble arsenic released at pH values above 7 is increased by the presence of phosphates; the digestive juices of all insects investigated contained phosphates.

Table 10.—Effect of hydrogen-ion concentration on the solubility of arsenic in magnesium arsenate.*

pH	Soluble Arsenic as As_2O_5, Milligrams Per Liter After					
	1 Hour	2 Hours	5 Hours	10 Hours	25 Hours	50 Hours
1.93	602	608	602	600	601	599
3.06	588	596	596	597	599	599
4.01	549	599	599	599	599	599
5.05	18	56	123	168	230	283
6.00	3	6	11	8	11	17
7.00	3	3	3	3	3	3
8.01	3	1	6	3	3	6
8.98	8	3	6	6	6	6
10.00	3	3	3	3	3	3

* 1.8787 grams magnesium arsenate used per liter.

Table 11.—Soluble arsenic formed by the decomposition of magnesium arsenate* in phosphate buffer solutions.

pH of Solution†	Soluble Arsenic as As_2O_5, Milligrams Per Liter After				
	1 Hour	5 Hours	10 Hours	25 Hours	50 Hours
2.0	600	596	598	600	615
3.0	598	604	598	600	610
4.0	415	600	600	604	610
5.0	192	266	270	278	292
6.0	74	118	130	142	156
7.0	34	55	81	78	80
8.0	25	34	33	32	32
9.0	14	24	30	30	32
10.0	14	22	26	32	32

* 1.8787 grams magnesium arsenate per liter. The arsenate analyzed 33.0 per cent As_2O_5.

† The proper pH was maintained by the addition of acetic acid.

An obvious conclusion from consideration of the above statements is that it should be possible to correlate the relative order of toxicity of these arsenates to insects with the amount of soluble arsenic released from these poisons in solutions having the same pH as the digestive juices of the insect. The amounts of soluble arsenic formed in phosphate solutions of known pH, as determined in the preceding section, are shown graphically in fig. 1. If the above conclusion is correct, it should be possible by the use of this graph to determine the relative order of toxicity

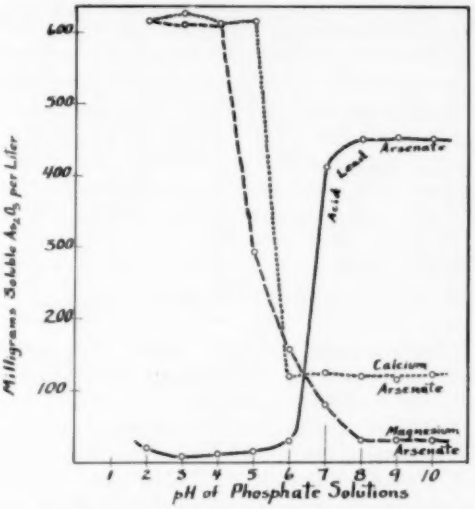

FIG. 1.—Soluble arsenic formed from acid lead, calcium and magnesium arsenates in phosphate solutions of various hydrogen-ion concentrations.

of acid lead, calcium and magnesium arsenates to an insect, if the pH in the insect's mid-gut is known. For example, for an insect whose mid-gut had a pH of 5.0, calcium arsenate should be most toxic, magnesium next and acid lead least toxic; while for an insect whose mid-gut had a pH of 10.0, acid lead arsenate should be most toxic, calcium next and magnesium least toxic.

It was proposed, therefore to test the validity of this assumption by determining the relative toxicities of these three arsenates to a series of leaf-feeding insects representing as wide a range as possible in the pH of their mid-gut contents.

METHODS OF DETERMINING RELATIVE TOXICITIES OF THE THREE ARSENATES.—Two ways of securing the desired information on relative toxicities appeared possi-

ble. One was to feed known equivalent dosages of each poison to a number of insects and record the time required to cause death. This is, of course, very desirable and, while it has been found possible to do this in the case of a few insects, no method has yet been devised which is applicable to a wide range of insects. The other way was to feed dosages of each poison so many times greater than that required to kill that the amount ingested by individual insects could be disregarded. For this purpose the methods used by Richardson & Glover (1932) appeared suitable, and the following modification of this method was used.

A thick coating of a powdered insecticide was applied inside the bottom half of a Petri dish; the insects were introduced and covered with the top half of the dish. As the mouths of chewing insects are located ventrally, they were in constant contact with the dusts as the insects walked around inside the dish, and the working of the mouthparts forced large amounts of the dust into the digestive tract. Checks were run by placing insects in empty Petri dishes. Every two hours the dead were counted and removed.

This method appeared suitable for practically all insects tested, except those with very short fore-guts. In these cases the more readily soluble poisons caused paralysis before much of the poison had been ingested, and more slowly soluble poisons killed more quickly than rapidly soluble poisons, due to the much larger amounts of poison ingested. This difficulty was overcome by removing all groups to clean Petri dishes as soon as any group stopped moving.

The number killed was then plotted against the hours required to kill, and the number of hours required to kill 25, 50, 75 and 100 per cent determined. The averages of all tests are reported in table 12. The results were analyzed by the statistical methods given by Snedecor (1934) for significant differences at 50 and 100 per cent mortality. At 50 per cent mortality the minimum difference necessary between means for the differences to be considered significant was determined based on odds of 19 to 1.

Cage experiments in which the insects were fed on foliage sprayed with the three arsenates at rates equivalent to 1 pound acid lead arsenate to 50 gallons of water gave the same order of toxicity as the Petri dish method described above. This was tried as a check on the above method with the Colorado potato beetle, the walnut caterpillar and the tomato worm.

Table 12.—Relative toxicity of acid lead, calcium and magnesium arsenates to certain insects at 25, 50, 75 and 100 per cent mortality.

Insect	Approx. pH in Mid-Gut	Average Number Hours Required by Various Arsenates to Kill											
		25 Per Cent			50 Per Cent			75 Per Cent			100 Per Cent		
		Pb	Ca	Mg	Pb	Ca	Mg	Pb	Ca	Mg	Pb	Ca	Mg
Mexican bean beetle	6.0	10.6	8.3	7.4	14.2	11.0	9.4	16.6	13.5	12.1	18.5	15.4	13.7
Colorado potato beetle	6.3	18.3	6.5	4.5	19.0	10.2	9.0	25.3	19.4	17.2	32.0	27.0	25.0
Boll weevil	6.5	15.4	11.0	12.5	19.3	12.3	17.7	25.3	16.8	21.3	32.0	24.3	28.0
Banded cucumber beetle	6.6	13.0	13.3	14.7	14.5	15.3	16.2	18.3	18.0	20.0	22.3	22.0	22.7
Click beetle	7.3	—	—	—	14.0	17.2	17.2	17.0	18.8	19.7	19.0	20.0	22.0
Corn ear worm	8.0	7.0	13.0	16.0	9.7	16.9	21.3	17.2	19.5	26.8	23.3	29.0	36.7
Walnut caterpillar	9.5	17.0	41.0	46.7	15.2	30.0	52.6	19.2	44.2	60.4	20.8	54.0	71.4
Tomato worm	9.6	4.3	9.0	24.2	10.5	18.3	42.0	17.7	25.7	52.8	23.7	31.3	69.7

Results of Tests With Mexican Bean Beetles, *Epilachna varivestis* Muls. —The pH in the mid-gut of adults of this species was approximately 6.0. The results reported in table 12 are the averages of eleven separate tests conducted at intervals throughout the summer and fall months on adult beetles. A statistical analysis of the results indicated that significant differences existed between the averages for these arsenicals at 50 per cent and 100 per cent mortality. At 50 per cent mortality the minimum difference in the averages which could be considered significant was 1.5 hours. It would, therefore, appear that the three arsenicals must be considered as differing in toxicity to the Mexican bean beetle, magnesium arsenate being most toxic, calcium arsenate a close second, and acid lead arsenate least toxic. By examination of the solubility of the arsenic in the three arsenicals at pH 6.0, fig. 1, it will be seen that this is the exact order of their theoretical toxicities to this insect.

RESULTS OF TESTS WITH COLORADO POTATO BEETLE, *Leptinotarsa decimlineata* Say.—The pH in the mid-gut of adults of this species was approximately 6.3. The results given in table 12 are the averages of five separate tests upon the adults. A statistical analysis of the results indicated that at 50 per cent mortality a minimum difference between the averages which could be considered significant was 4.2 hours. It would appear, therefore, that no significant difference was demonstrated between the toxicities of calcium and magnesium arsenates, but that acid lead arsenate was significantly less toxic than either of the other two arsenicals. By reference to fig. 1, the theoretical toxicities of the three arsenicals at pH 6.3 are seen to be as follows: magnesium arsenate should be only slightly more toxic than calcium arsenate, and acid lead arsenate considerably less toxic than either of the other two. While no difference in toxicity was demonstrated between magnesium and calcium arsenate, very close agreement is evident between the theoretical and actual relative toxicities.

RESULTS OF TESTS WITH STRIPED BLISTER BEETLE, *Epicauta vittata* F.—The pH in the mid-gut of adults of this species was approximately 6.6. The results given in table 12 are the averages of three closely agreeing tests conducted simultaneously with adults. A statistical analysis of the results indicated that at 50 per cent mortality a minimum significant difference between the averages would be 3.9 hours. It would appear then that no significant differences existed between the averages reported, and by reference to fig. 1, it may be seen that at pH 6.6 the solubility of the three arsenicals is approximately equal.

RESULTS OF TESTS WITH BOLL WEEVIL, *Anthonomus grandis* Boh.—The acidity of the mid-gut of this insect averaged pH 6.5, but individual weevils varied from pH 6.2 to 7.1. The results on toxicity likewise varied in the four tests which were conducted.

A statistical analysis of the results in table 12 indicated that no differences were demonstrated between treatments, the minimum significant difference necessary between averages at 50 per cent mortality being 6.8 hours. By reference to fig. 1, it appears that the acidity of the digestive juices of this insect varies around the point where these arsenates should be approximately equal in toxicity.

RESULTS OF TESTS WITH CLICK BEETLE, *Monocrepidius lividus* (De G.).—The pH in the mid-gut of adults of this species averaged 7.3. The results given in table 12 are the averages of three closely agreeing tests which were run simultaneously. No points were located for the 25 per cent mortality. The minimum difference between averages which could be considered significant at 50 per cent mortality is 1.7 hours. It is apparent that acid lead arsenate was most toxic, while no significant difference in toxicity was demonstrated between calcium and magnesium arsenates. Data in fig. 1 indicate that acid lead arsenate would be expected to be most toxic, calcium next and magnesium least toxic. The difference between the toxicities of calcium and magnesium arsenates, however, would be expected to be much less than that between these arsenates and acid lead arsenate. Fairly close agreement is evident, therefore, between the actual and theoretical toxicities, although no difference was demonstrated between the relative toxicity of calcium and magnesium arsenate.

RESULTS OF TESTS WITH CORN EAR WORM, *Heliothis obsoleta* (F.).—The mid-gut of the larvae of this insect had a pH 8.0. The results given in table 12 are the averages of three closely agreeing tests on the larvae which were run simultaneously. A statistical analysis indicated that the smallest difference between the averages which could be considered significant at 50 per cent mortality was 1.4 hours. It would appear, therefore, that significant differences between the relative toxicities of the three arsenates were demonstrated by these tests. Acid lead arsenate was most toxic, calcium arsenate was next and magnesium arsenate was least toxic. This is in agreement with the theoretical order of their relative toxicities as indicated by fig. 1.

RESULTS OF TESTS WITH WALNUT CATERPILLAR, *Datana integerrima* G. & R.—The mid-gut of the walnut caterpillar had an average pH of 9.5. The results given in table 12 are the averages from five series of tests. A statistical analysis of the results indicated that significant differences existed between the averages at 50 per cent mortality and also at 100 per cent mortality. The smallest difference in

averages at 50 per cent mortality which could be considered significant was 7.2 hours. It would appear, therefore, that the arsenates were toxic to this insect in this order: acid lead arsenate, calcium arsenate and magnesium arsenate, the last being the least toxic. This is also seen to be the relative order of their theoretical toxicities as shown in fig. 1.

RESULTS OF TESTS WITH TOMATO WORM, *Protoparce sexta* (Johan.).—The average pH of the mid-gut of the larvae of this species was 9.6. The results given in table 12 are the averages of three closely agreeing tests on larvae which were run simultaneously. A statistical analysis indicated that the least difference which could be considered significant between the averages at 50 per cent mortality was 5.3 hours. Apparently, therefore, the order of toxicity of the arsenates to this insect is acid lead arsenate, calcium arsenate and magnesium arsenate, the last being least toxic. These results are in agreement with the theoretical order of toxicity as indicated by fig. 1.

SUMMARY.—Phosphates were found to be a component of the digestive secretions of the nine species of insects used in these tests.

The formation of soluble arsenic from acid lead arsenate, calcium arsenate and magnesium arsenate was largely dependent on the hydrogen ion concentration of the solution. It was influenced to a lesser extent by the concentration of acids, bases and salts in the solution.

The presence of phosphates greatly increased the amount of soluble arsenic formed from acid lead arsenate in alkaline solutions. This was apparently due to precipitation of part of the lead as lead phosphate, as this compound was found to be very insoluble in alkaline solutions. Phosphates influenced the solubility of the arsenic in calcium and magnesium arsenates to only a slight extent.

The relative toxicity of acid lead arsenate, calcium arsenate and magnesium arsenate to nine species of phytophagous insects was shown to be correlated with the relative amounts of soluble arsenic formed from these arsenates in phosphate solutions having the same pH as was found in the mid-guts of these insects.

For insects having an alkaline reaction in their mid-gut, acid lead arsenate was most toxic and magnesium arsenate least toxic; for insects having an acid reaction of pH 6.0 in their mid-gut, magnesium arsenate was most toxic and acid lead arsenate least toxic.

It appears possible to predict the relative order of toxicity of acid lead arsenate, calcium arsenate and magnesium arsenate to chewing insects, if the hydrogen ion concentrations in the insects' mid-guts are known.—4-9-38.

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The Hydrogen-Ion Concentration of Myiotic Wounds in Sheep and Goats

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The hydrogen-ion concentration of myiotic wounds in guinea pigs and its relation to the oviposition stimulus of gravid females of *Cochliomyia americana* C. & P., the screwworm fly, were presented by the senior author in a paper read at the Thirty-third Annual Meeting of the American Society of Tropical Medicine which was held at New Orleans, La., November 30 to December 3, 1937.

That paper briefly listed the following results: (1) The mean pH of wounds in guinea pigs having lethal and sublethal infestations of screwworms showed a significant increase in alkalinity on the third day of myiasis. (2) For the remainder of the myiotic period the alkalinity diminished only slightly in the case of those having lethal infestations but decreased more markedly with those having sublethal infestations. (3) During the postmyiotic period the mean pH changed to the acid side in the case of all animals that survived, whereas in all that succumbed it remained on the alkaline side. (4) A positive relationship between the maximum attractiveness of myiotic wounds to gravid females of *C. americana* and the period of greatest alkalinity of wound exudates was distinctly indicated.

EXPERIMENTAL PROCEDURE.—The present paper is a report on the determination of the hydrogen-ion concentration of exudates of 32 wounds in goats and of 20 wounds in sheep infested with the larvae of *C. americana*.

The experimental animals were fairly uniform as to age and size. Incisions, 1½ inches long and extending through the connective tissue underlying the skin, were made with a knife or razor blade. The wounds, one on each side, were located on the rump about 3 inches behind the hip. About 100 first-instar larvae were implanted in each fresh wound.

Colorimetric determination of the pH values of the wound fluids was made daily, beginning with the fresh (uninfested) wound and continuing through myiotic and postmyiotic periods. Wounds

* Early publication of this paper has been secured by payment of the printing charge.

that had closed or scabbed over during the postmyiotic period were punctured or squeezed sufficiently to discharge a sample of the enclosed fluid or pus. Tests were discontinued when wounds had healed to the extent that fluids other than blood were no longer present.

RESULTS OF TESTS.—The results of these tests are presented in fig. 1. A comparison of the trend of the mean pH

guinea pigs are highly attractive to gravid females of *C. americana*, it is reasonable to assume that postmyiotic wounds in sheep are more attractive to the flies than similar wounds in goats.

It is well known that postmyiotic wounds remain attractive for a longer period in some animals than in others. In field work it has been observed that wounds producing a watery discharge do

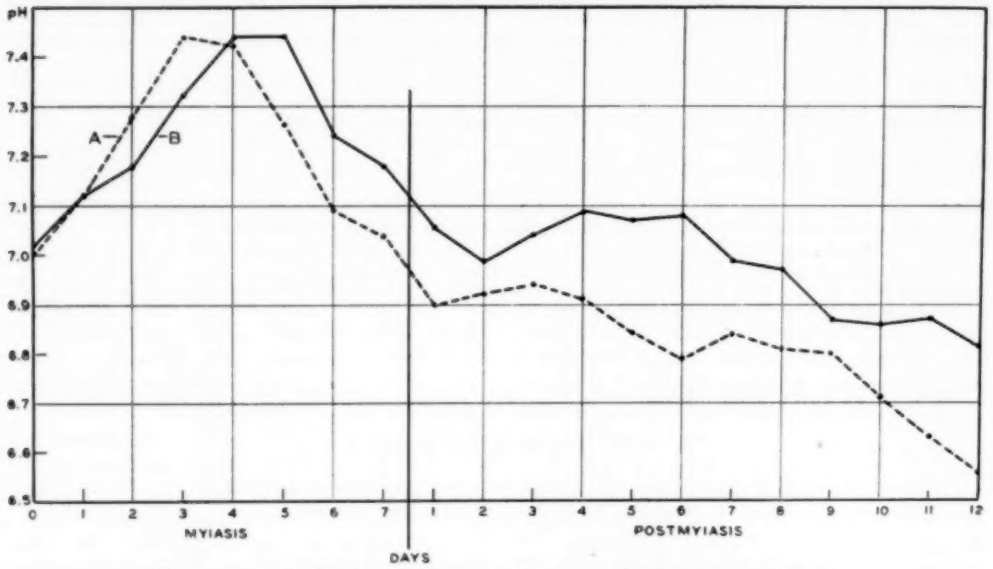

FIG. 1.—Graph showing the hydrogen-ion concentration of myiotic and postmyiotic wounds in (A) goats and (B) sheep.

courses in myiotic rump wounds of sheep and goats shows that these courses are similar except that the changes occur sooner in goats than in sheep. The period of infestation, however, was practically the same in both species of hosts. The alkalinity is comparatively high from the third to the sixth day. This period, and also the peak reached in wounds in both sheep and goats, is of considerably greater magnitude than that reported for myiotic wounds in guinea pigs. This is of distinct importance, since it has been demonstrated with guinea pigs that a high alkalinity in myiotic wounds is highly attractive to gravid females of *C. americana*.

The course of the mean pH of postmyiotic wounds in goats is toward greater acidity as long as pus is present, whereas in sheep it is alkaline or near-alkaline for the entire period. Therefore, since it has been shown that alkaline wounds of

not promptly heal and are exceedingly attractive to gravid blowflies for a long time. Other wounds which are filled with a viscous discharge scab over quickly and are much less attractive to blowflies. In the experiments with guinea pigs it was found that wounds discharging watery fluid are definitely alkaline, whereas wounds of the other type, which scab quickly, are generally acid in reaction.

This information should prove to be of considerable economic importance as a guide in the selection of chemicals to be tested as larvicides, ovicides and repellents. In addition, it suggests a treatment for long-draining or slowly healing postmyiotic wounds—; namely, to acidify the wound by either local or internal medication. This is confirmed by the results of studies of other septic wounds by Apostoleanu and Vladutiu (1936) and many other physicians who have studied wound

healing. Their findings show that acid-producing diets and local acidifications give markedly favorable results in the healing of various wounds.—4-11-38.

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A Chemical Study of Mixtures of Lime Sulfur and Lead Arsenate[1]

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Early studies of the lead arsenate and lime sulfur combination, which has become the most common arsenical-fungicidal mixture, indicated that the two components exhibited tendencies to reduce the effectiveness of each other and promote injury to the plant surfaces.

Investigations of the mixture of lead arsenate and lime sulfur both with and without modifying materials have been reported. These investigations have been for the most part attempts to produce spray mixtures without undesirable properties, while maintaining the maximum insecticidal and fungicidal values. Such studies have been based in most cases on practical field experiments, and comparatively little is known of the chemical changes involved in the mixture. Such chemical studies as have been reported have been made with the idea of reducing the soluble arsenic present in the mixture, since the consensus is that this is the principal causative agent in spray injury to plants.

This investigation, dealing as it does only with the chemical changes which occur in the spray solution before application to the host plant, can not answer all the questions concerning the suitability of the spray mixtures studied for practical use. The changes that take place in the film of spray after it has been applied to the plant surface are of major importance, but their study lies outside the field of the present paper. The usefulness of this investigation then lies in the contribution which it may make to the knowledge of the chemistry of the reaction between lead arsenate and lime sulfur under certain specific conditions. It is, however, possible to point out certain implications from the results of this work which may be of considerable practical value.

PREVIOUS STUDIES.—The problem of spray injury by lead arsenate and lime sulfur mixtures has been recognized for many years and has been investigated by many workers, including Fernald & Bourne (1922), Swingle, Morris & Burke (1923), Mogendorff (1925), Ginsburg (1929), Young (1930) and others. The consensus appears to be that the injury is caused by soluble arsenic, and that the amount of soluble arsenic is increased by the addition of lime sulfur. Certain correctives have been suggested to reduce the amount of the injury, and include a variety of substances. Of those suggested, slaked lime and dried skim milk powder alone and in combination have been studied in this work.

The active fungicidal agent present in lime sulfur solutions has been established by Abbott *et al.* (1926), Holland *et al.* (1921) and Tartar (1914) as that form of sulfur present as the calcium polysulfides. Whether the actual mechanism of the toxic action is through its solvent action as suggested by Tartar (1914), through the action of hydrogen sulfide formed or by some other means need not be discussed here.

THE PRESENT PROBLEM.—It appears then that, aside from those compounds such as the thiosulfates, sulfates and others the determination of which under various conditions gives information as to

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the mechanism of the chemical reactions between the components of the mixture, the two most important constituents of any spray mixture having as its basis lime sulfur and lead arsenate are the soluble arsenic and the polysulfide sulfur. The ideal condition would be to keep the former as low and the latter at as high a level as possible in the mixture.

The following experiments have been planned to indicate the chemical changes which take place in lime sulfur solutions when used in combination with lead arsenate alone and with recognized adjuncts: lime and dried skim milk powder. These studies included not only the determination of soluble arsenic and soluble calcium but also a quantitative investigation of the soluble sulfur compounds present in the mixtures, of which the polysulfide sulfur has been considered to be the active fungicidal agent. Studies were also made on the effect of various physical factors such as temperature, time of agitation, etc., on the decomposition of lime sulfur alone and in mixtures.

In preparing the experimental mixtures, conditions used in commercial orchard practice were followed as far as possible. The period of agitation of the mixtures was limited to one hour as the maximum time that a spray solution remains in the spray tank under constant stirring.

MATERIALS USED.—The following materials were used in the experiment.

Liquid Lime Sulfur.—A commercial grade, concentrated lime sulfur solution was used having a specific gravity of 1.2762 and a Baumé reading of 31.62 degrees. Its total sulfur content was 24.05 per cent.

Acid Lead Arsenate.—A chemically pure powder purchased from the Baker Chemical Company. On analysis it was found to contain:

	Per Cent
Total PbO	65.70
Total Arsenic Oxide	31.98
Water Soluble Arsenic as As_2O_5	0.53
Moisture	0.50

Calcium Hydroxide.—A chemically pure grade, heated before use to insure removal of carbonates.

Skim Milk Powder.—A commercial product prepared for spray purposes, yellow in color and containing by analysis 69.23 per cent protein. It was separated by screening before use and a single size used for all of the experiments. This passed through a 60- but not 80-mesh screen.

PREPARATION OF EXPERIMENTAL MIXTURES.—After mixing the several ingredients, whatever the number chosen, the final volume was brought to one liter. The manipulation was as follows in all cases: Approximately 900 ml. of water were placed in a 2-liter beaker fitted with a ground glass top and an electric stirrer. Unless otherwise noted, distilled water was used. The solid ingredients were added to the water and, while the mixture was stirred, lime sulfur concentrate was added in quantity sufficient for the dilution desired. Water was then added to make the final volume of one liter. The mixture was stirred for the period desired at a constant rate of 200 revolutions per minute. The mixture was filtered immediately through a Gooch crucible fitted with a hard filter paper base.

The filtrate was sampled (without washing the residue) for total sulfur, sulfide sulfur, thiosulfate sulfur, calcium and soluble arsenic by the methods indicated below.

The residue was washed with a very small quantity of cold distilled water until the washings were free from the yellow color of lime sulfur solution. The residues were dried for two hours at 60 degrees and retained in vacuo over sulfuric acid until constant weight was reached.

If the filtrate was to be stored for later analysis, the container was filled to exclude air, capped and waxed, and stored in a dark place.

METHODS OF ANALYSIS.—The methods used for determining total sulfur, sulfide sulfur, thiosulfate sulfur and water soluble arsenic (hydrazine sulphate and sodium bromide distillation) were those given in the Official Methods of the Association of Official Agricultural Chemists (1935). Calcium was determined by the McCrudden (1911) method as modified by Halverson & Shulz (1920). Hydrogen sulfide was estimated by placing the closed system under a slight vacuum and drawing the evolved gas through a solution of cadmium chloride as suggested by Scott (1925).

EFFECT OF DILUTION ON THE CONSTITUENTS OF LIME SULFUR CONCENTRATE.—The concentrated lime sulfur solution, specific gravity 1.2762 and

Table 1.—Effect of temperature on the constituents of diluted lime sulfur.

Quarts Concentrate Per 100 Gallons	4		8		12		16	
Dilution Radio of Lime Sulfur	1–100		1–50		1–33.3		1–25	
Temperature in Degrees C.	23	32	23	32	23	32	23	32
Total Sulfur (g. per 100 gal.)	1118.500	1101.600	2244.200	2183.200	3370.800	3321.500	4487.600	4398.900
Sulfide Sulfur (g. per 100 gal.)	1042.900	1015.700	2106.800	2036.600	3161.400	3075.700	4209.200	4059.600
Thiosulfate Sulfur (g. per 100 gal.)	67.200	74.100	124.800	142.800	186.900	215.000	248.800	302.800
Sulfate Sulfur (g. per 100 gal.)	8.400	12.000	15.200	23.800	22.500	30.800	29.600	36.500
Calcium (g. per 100 gal.)	326.500	329.400	650.800	651.600	975.900	973.900	1299.600	1301.600
Sulfide Sulfur (per cent)	93.500	92.200	93.870	92.280	93.780	92.600	93.790	92.280
Mol Ratio S/Ca (as sulfide)	4.757	4.734	4.755	4.779	4.755	4.798	4.752	4.767

Baumé 31.62 degrees, was diluted to various degrees between 1–10 and 1–200 and analyzed as a preliminary experiment. The analyses indicated that within the dilution range studied and under comparable conditions there was no appreciable change in the percentage of the constituents of the solutions. The oxidation change appeared to proceed slowly during the first hour under these conditions and the differences in the percentage of the active sulfide in the diluted solutions were considered negligible from a practical standpoint.

EFFECT OF TEMPERATURE VARIATION.—The concentrated lime sulfur was diluted in proportions of 1–25, 1–33.3, 1–50 and 1–100. These mixtures were prepared according to the standard procedure and were stirred at a constant temperature of 32 degrees C. Table 1 is a comparison of the analyses of these solutions with similar mixtures prepared at 23 degrees C.

A rise in temperature increased the rate of decomposition of the mixtures, resulting in a decreased percentage of sulfide sulfur in the solution. There was also an increase in thiosulfate sulfur in compensation to the loss of sulfur as the sulfide. Little change appeared in secondary products resulting from the decomposition. The actual percentage of the sulfide sulfur in the solution decreased approximately $1\frac{1}{2}$ per cent.

The increase in the ratio of sulfur to calcium in the sulfide form in the solutions, as the temperature was increased, indicated a rise in the concentration of the polysulfide in solution as compared to the total sulfur in solution. Since the total calcium in the solution remained at the same level within limits of experimental error, and the sulfur as the sulfate increased only to a slight degree, it appeared that the change due to increased temperature resulted from an increased hydrolysis of the mixture. Sulfur was lost from the solution, apparently as hydrogen sulfide, since no free sulfur was precipitated from the solution. The free sulfur, which is normally precipitated from lime sulfur solution on oxidation and formation of the thiosulfate and sulfate sulfur, was then redissolved in the solution, where it retained the sulfide concentration at its high level.

EFFECT OF TIME.—Concentrated lime sulfur diluted 1–50 was prepared and stirred according to the standard procedure at a constant temperature of 23 degrees C. for periods ranging between 1 and 45 hours. Analyses were made of each of the solutions in order to determine the extent of the decomposition process.

Under the conditions of the experiment, the sulfide sulfur of the solution was almost entirely removed in 45 hours, table 2. The loss of sulfur as the sulfide was proportional to the increase in the concentration of the thiosulfate sulfur and sulfate sulfur in solution. The decomposition progressed slowly in the initial stages but appeared to increase rapidly in the later stages of agitation.

Table 2.—Effect of time of stirring on the constituents of lime sulfur diluted 1–50 (23 degrees C.).

HOURS STIRRED	1	5	10	20	30	40	45
Total Sulfur (g. per 100 gal.)	2244.200	1912.000	1630.400	1318.100	1067.600	789.600	758.300
Sulfide Sulfur (g. per 100 gal.)	2106.800	1702.600	1347.100	916.600	523.600	189.900	11.100
Thiosulfate Sulfur (g. per 100 gal.)	124.800	154.300	201.500	301.100	377.200	443.000	607.600
Sulfate Sulfur (g. per 100 gal.)	15.200	55.100	81.800	100.400	166.800	156.700	139.600
Calcium (g. per 100 gal.)	650.800	652.600	635.400	623.800	645.800	647.700	652.300
H_2S Evolved (g. per 100 gal.)	2.000	10.200	12.400	12.600	11.200	11.900	12.100
Sulfide Sulfur (per cent)	93.870	98.040	82.630	69.540	49.040	24.050	1.460
Mol Ratio S/Ca (as sulfide)	4.755	4.437	3.695	3.411	2.945	1.939	0.141

Free sulfur was precipitated from the solution during the first five hours and continued to be precipitated throughout the 45 hour period. From the analyses it appears that during the period approximately one-third of the total sulfur present in the solution was precipitated as the free sulfur. Hydrogen sulfide evolved from the mixture was small, indicating that the decomposition was primarily due to oxidation. As the solution became more dilute with respect to the concentration of the polysulfides, the oxidative process was increased.

The ratio of sulfur to calcium in the sulfide form in the solution decreased at a regular rate, indicating that sulfur as free sulfur was the only oxidative product lost from solution. The loss of calcium during the middle stages of the decomposition and its recovery towards the end of the stirring period may be due to a precipitation of oxidation products later redissolved in solution as the thiosulfate and other oxidation products increase. These results agree with the analyses reported by Fernald (1907).

EFFECT OF ADDITION OF ACID LEAD ARSENATE.—Workers agree that the addition of acid lead arsenate to lime sulfur solutions results in a loss of sulfide sulfur from the solution and an increase in thiosulfate and sulfate sulfur. In addition a residue is formed and precipitated. There is further, reduction in soluble sulfur due to the precipitation of lead sulfide and the formation of an arsenate of calcium. The loss of sulfur due to the formation of lead sulfide has been regarded as the cause of the removal of calcium from the solution. It has been claimed by Goodwin & Martin (1925) and by Ruth (1913) that thioarsenates are formed in the process.

Dilutions of the concentrated lime sulfur solution were prepared which ranged between 1–10 and 1–200. Lead arsenate was added to the dilute lime sulfur in amounts equivalent to 3 pounds in 100 gallons of solution. Each member of the series was treated according to the standard procedure at a constant temperature of 23 degrees C. The results of the analyses, table 3, were calculated on the basis of grams in 100 gallons of mixture.

The relative proportions of the constituents in the diluted mixtures did not vary directly with dilution as in the case of lime sulfur solutions prepared in a similar manner. The actual percentage of sulfide sulfur present in the solution was practically constant in dilutions more concentrated than 1–50. In the very dilute solutions there was an increase in the amount of thiosulfate and other soluble oxidation products which suggests that the loss of sulfur as the sulfide was not due in these cases to the direct addition of lead arsenate but rather to an increased oxidation of the mixture in the presence of lead arsenate.

The addition of lead arsenate measurably reduced the sulfide content of the more dilute mixtures. However, in solutions of higher concentration, the percentage change of the sulfide sulfur was small. For example, in the 1–200 dilution, the percentage of sulfide sulfur was reduced from 92.25 to 14.89 per cent. For the 1–10 mixture, however, the loss was only from 93.82 per cent to 92.78 per cent.

The sulfide concentration in the 1–10 dilution of the mixture, calculated upon the basis of the total sulfur added to the solution, shows a greater reduction of sulfide from the solution. These values show a reduction of from 93.82 per cent to 88.84 per cent.

Table 3.—Effect, on the constituents of the solutions, of the addition of three pounds of lead arsenate to diluted lime sulfur solutions.

QUARTS CONCENTRATE PER 100 GALLONS	2	4	8	12	16	20	40
DILUTION RATIO OF LIME SULFUR	1–200	1–100	1–50	1–33.3	1–25	1–20	1–10
Total Sulfur (g. per 100 gal.)	87.300	605.400	1765.300	2902.700	4016.700	5145.600	10577.500
Sulfide Sulfur (g. per 100 gal.)	13.100	470.200	1576.400	2632.300	3706.600	4773.600	9806.200
Thiosulfate Sulfur (g. per 100 gal.)	67.800	108.200	145.400	197.800	250.400	298.900	615.700
Sulfate Sulfur (g. per 100 gal.)	6.400	27.000	43.500	52.600	59.700	73.100	156.600
Calcium (g. per 100 gal.)	66.700	223.700	543.200	851.600	1163.600	1483.900	3064.400
Soluble As_2O_5 (g. per 100 gal.)	19.900	17.100	12.100	9.000	7.800	6.600	6.200
Residue (g. per 100 gal.)	1701.700	1964.400	1978.800	1992.500	1998.800	1819.900	1662.900
Sulfide Sulfur (per cent)	14.890	77.660	89.290	90.680	92.280	92.770	92.780
Mol Ratio S/Ca (as sulfide)	1.010	4.855	4.952	4.969	4.967	4.947	4.935

The relative increase in the calcium polysulfide concentration is illustrated in the sulfur to calcium ratio in the sulfide form. The increase of the ratio from an average value of 4.755 in the case of lime sulfur alone to a value of 4.954 indicates that the proportion of the pentasulfide in the mixture has increased due to the addition of the lead arsenate to solutions more concentrated than 1–50.

The increase in the ratio may be traced to the decomposition of lead arsenate by hydrogen sulfide in the solution. As the lead is precipitated from the lead arsenate, calcium is removed from the calcium polysulfide by arsenic acid produced and precipitated from the solution as an arsenate of calcium. Removal of calcium from the solution in a constant quantity and in a greater proportion than the loss of sulfur either as the sulfide of lead or as free sulfur should increase the molecular ratio between them.

According to Thatcher & Streeter (1924) and Young (1930), the extent of hydrolysis of the polysulfides resulting in the formation of hydrogen sulfide in lime sulfur solution appears to be dependent upon the dilution of the solution. The increased formation of soluble arsenic in the solutions from lime sulfur and lead arsenate mixtures as the dilution was increased would appear as a result of an increased formation of hydrogen sulfide and also as an aid to the further decomposition of the polysulfide in the solution.

EFFECT OF TYPE OF WATER.—An experiment was performed using distilled water, tap water and water freed from carbon dioxide as the diluting agents. The lime sulfur solutions were prepared according to the standard procedure in which a dilution of 1–50 of the lime sulfur was used. Lead arsenate was added in the proportion of three pounds in 100 gallons. The results indicated that there was little difference in the primary sulfur containing compounds in the mixture when the different waters were used. Comparative results may be obtained using any of these waters, although the results could be more readily duplicated if distilled water were used.

EFFECT OF TIME AND TEMPERATURE—In a series mixtures of lime sulfur and lead arsenate the lime sulfur was diluted at the rate of 1–50 and lead arsenate added in the proportion of 3 pounds in 100 gallons. The mixtures were prepared according to the general procedure. Each mixture was stirred for a period and the solution analyzed. Successive mixtures were prepared and sampled after longer periods until an analysis of the solutions indicated a disappearance of the sulfide sulfur in the solution. Constant temperatures in the two series of experiments were maintained at 23 degrees C. and 32 degrees C. The results are shown in figs. 1 and 2.

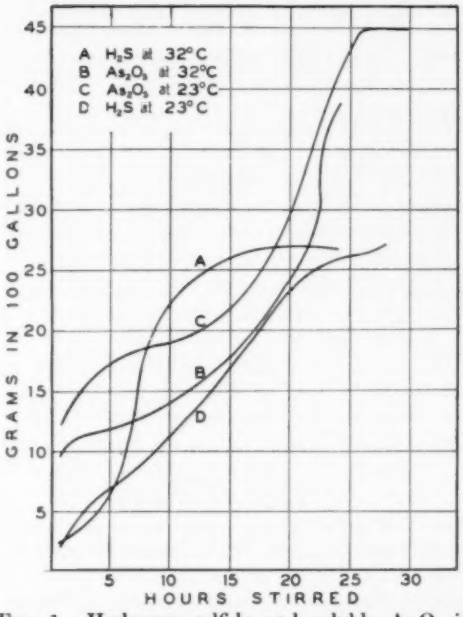

FIG. 1.—Hydrogen sulfide and soluble As_2O_5 in relation to time of stirring and temperature.

The decomposition of the polysulfides in the solution when in contact with lead arsenate proceeded rapidly during the first hour of contact and between the fourth and tenth hours, after which the decomposition appeared to be constant.

A decrease in the sulfide sulfur content was reflected to some extent by an increase in the thiosulfate sulfur soluble in the solution. However, the greatest loss to the solution was the free or precipitated sulfur passing into the residue. Partial analyses of the residues showed that the proportion of free sulfur precipitated increased to approximately the twenty-second hour, beyond which there was no appreciable increase. Thereafter the loss of sulfur from the sulfide may be accounted for by an increase in the thiosulfate sulfur in solution.

The proportion of sulfur remaining, calculated as the sulfate, showed a marked increase between the sixteenth and twenty-fourth hours, where the precipitation of sulfur as free sulfur ceased and the increase in thiosulfate sulfur in the solution was at its greatest rate.

Complete decomposition of the sulfide

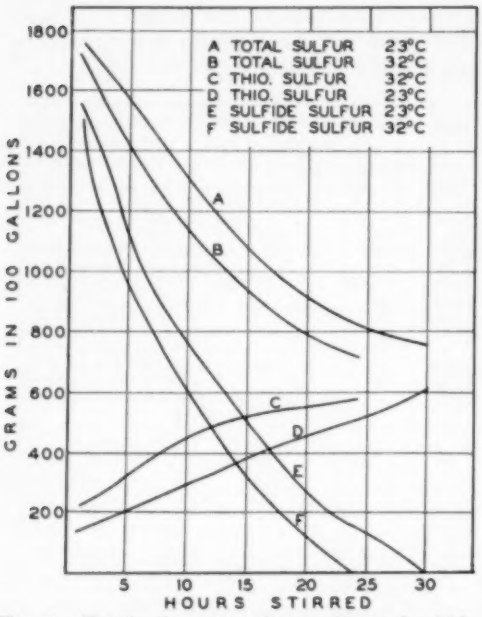

FIG. 2.—Total sulfur, thiosulfate sulfur and sulfide sulfur in relation to time of stirring and temperature.

was reached in 30 hours in the mixture stirred at 23 degrees C. The sulfide sulfur in the mixtures stirred at a temperature of 32 degrees C. was completely removed in 23 hours.

The principal effect of a change in temperature was an alteration of the rate of decomposition process as shown in fig. 1. The curves are comparative over the entire range of the stirring period and progress in a similar manner independent of the temperature.

The water soluble arsenic in the mixtures stirred at 32 degrees C. was less than the amount found in the solutions stirred at 23 degrees C. Fig. 2 shows the relation between the temperatures and the presence of soluble arsenic and hydrogen sulfide in the solutions. At the higher temperature the hydrogen sulfide was more quickly removed from the solution. It thus prevented the reaction between it and lead arsenate from forming arsenic acid as the end product of the reaction.

The soluble arsenic in the mixture of lime sulfur and lead arsenate stirred at 23 degrees C. increased at a constant rate to the sixteenth hour, when there was an abrupt rise in the proportion soluble in solution. This increase corresponded to the analyses for hydrogen sulfide evolved from the solution, which increased to approximately the sixteenth hour and thereafter was nearly constant. Similar curves are shown for analyses of the soluble arsenic and hydrogen sulfide on the mixture stirred at 32 degrees C. In this case, however, the change occurred at approximately the twenty-second hour of agitation.

EFFECT OF ADDED LIME.—The changes that occur in the composition of a spray of mixed lime sulfur and lead arsenate as shown by the analyses of solution in the previous experiments, particularly the marked reduction in the amount of polysulfide sulfur present in solution, emphasize the need for the addition of some material which will retard or completely overcome the tendency for chemical reaction between the members of the mixture.

The use of slaked lime to prevent the formation of soluble arsenic was proposed by Robinson (1919), who had previously shown that its use with acid calcium arsenate lowered the amount of soluble arsenic in the solution. He advised the addition of 10 pounds of lime to 100 gallons of lime sulfur solution previous to the addition of lead arsenate and indicated that the polysulfide content under these conditions decreased very little.

In order to determine the effect of lime on the combination of lead arsenate and lime sulfur, five dilutions were prepared which ranged between 1–20 and 1–100. These were treated according to the standard procedure with lime added in the proportion of 1 pound in 100 gallons of mixture. The analyses of these mixtures are shown in table 4 and are calculated in terms of grams in 100 gallons of the mixture.

From table 4 it appears that through the addition of 1 pound of slaked lime per 100 gallons of spray mixture the quantity of sulfur (both total and as the sulfide) in solution was greater than when no lime was present in a similar mixture of lead arsenate and lime sulfur. The difference in

Table 4.—Variation in the constituents of the solution when lime was added to diluted mixtures of lime sulfur and lead arsenate.

PROPORTION	4–3–1–0*	8–3–1–0	12–3–1–0	16–3–1–0	20–3–1–0
DILUTION RATIO OF LIME SULFUR	1–100	1–50	1–33.3	1–25	1–20
Total Sulfur (g. per 100 gal.)	1115.500	2245.800	3370.000	4491.100	5606.200
Sulfide Sulfur (g. per 100 gal.)	778.100	1795.700	2802.800	3817.000	4819.300
Thiosulfate Sulfur (g. per 100 gal.)	202.000	305.400	419.200	506.700	606.500
Sulfate Sulfur (g. per 100 gal.)	135.400	144.700	148.000	167.400	180.400
Calcium (g. per 100 gal.)	492.500	827.100	1159.500	1493.000	1821.100
Soluble As_2O_5 (g. per 100 gal.)	8.400	6.100	5.500	4.800	4.100
Residue (g. per 100 gal.)	1452.300	1467.200	1458.700	1463.600	1461.700
Sulfide Sulfur (per cent)	69.750	79.950	84.060	84.900	85.780
Mol Ratio S/Ca (as sulfide)	4.936	4.927	4.951	4.933	4.951

* The first figure represents quarts of lime sulfur concentrate; the second, pounds of lead arsenate; the third, pounds of slaked lime; the fourth, pounds of dried skim milk; all figures are on the basis of 100 gallons of spray mixture.

the per cent sulfide sulfur appeared as an increase in the total quantity of thiosulfate and sulfate sulfur in solution. These increased in the proportion of twofold and tenfold, respectively.

Excess calcium reduced the soluble arsenic in the mixtures to a minimum of 4.1 grams per 100 gallons as compared to a minimum of 6.2 grams in mixtures of lime sulfur and lead arsenate. In water solution, pure lead arsenate was soluble to the extent of 6.8 grams per 100 gallons.

The major effect of the addition of one pound of lime to diluted mixtures of lime sulfur and lead arsenate was a retention of sulfur in solution. Soluble arsenic was reduced to a minimum, and the ratio of sulfide sulfur to sulfide calcium retained at its high level. The difference between the weights of these precipitates and those of a similar series where lime sulfur and lead arsenate were combined (table 3) was 506.8 grams per 100 gallons. This value closely approximated the quantity of lead sulfide (507.3 grams) which was found on partial analysis of the residues from similar mixtures of lime sulfur and lead arsenate.

In order to determine the effect of the addition of larger quantities of lime to the lime sulfur and lead arsenate mixtures, lime sulfur was diluted to 1–50 and lead arsenate added at the rate of 3 pounds to 100 gallons. Lime was added to these in proportion varying between 8 ounces and 9 pounds per 100 gallons of solution. The values for the components of the solution, as shown in table 5, are calculated in terms of grams in 100 gallons of mixture.

The precipitation of sulfur resulting from the addition of lead arsenate was retarded when lime was added in any quantity between 8 ounces and 9 pounds.

The principal effect of the addition of lime was to increase the proportion of soluble oxidation products in the solution. In the mixtures analyzed which contained between 8 ounces and 3 pounds of lime, the state of the polysulfides in the solution appeared to be constant as indicated by the sulfur to calcium ratio. When 6 or 9 pounds of lime were added, the ratio indicated that the polysulfides in the solution were made up primarily of the tetrasulfide rather than the pentasulfide.

As the proportion of lime added to the solution was increased between the limits of 8 ounces and 9 pounds, an increased

Table 5.—Effect on the constituents of the solution when lime was added to mixtures of lime sulfur and lead arsenate diluted 1–50.

PROPORTION	8–0–0–0*	8–3–0–0	8–3–½–0	8–3–1–0	8–3–2–0	8–3–3–0	8–3–6–0	8–3–9–0
Total Sulfur (g. per 100 gal.)	2244.200	1765.300	2241.400	2245.800	2248.400	2252.000	2247.200	2244.500
Sulfide Sulfur (g. per 100 gal.)	2106.800	1576.400	1978.900	1795.700	1740.600	1706.500	1791.000	2038.400
Thiosulfate Sulfur (g. per 100 gal.)	124.800	145.400	181.700	305.400	310.200	373.400	344.600	150.400
Sulfate Sulfur (g. per 100 gal.)	15.200	43.500	80.800	144.700	197.600	172.100	111.600	55.700
Calcium (g. per 100 gal.)	650.800	543.200	714.800	827.100	891.600	904.600	919.400	946.400
Soluble As_2O_5 (g. per 100 gal.)		12.100	6.400	6.100	5.400	3.900	3.300	3.200
Residue (g. per 100 gal.)		1978.800	1417.100	1467.200	1802.500	2130.100	3325.200	4584.100
Sulfide Sulfur (per cent)	93.870	89.290	88.280	79.950	77.430	75.770	79.630	91.260
Mol Ratio S/Ca (as sulfide)	4.755	4.952	4.942	4.927	4.826	4.676	3.965	3.253

* The first figure represents quarts of lime sulfur concentrate; the second, pounds of lead arsenate; the third, pounds of slaked lime; the fourth, pounds of dried skim milk; all figures are on the basis of 100 gallons of spray mixture.

Table 6.—Effect on the constituents of the solution when dried skim milk was added to mixtures of diluted lime sulfur and lead arsenate.

PROPORTION	4–3–0–1*	8–3–0–1	12–3–0–1	16–3–0–1	20–3–0–1
DILUTION RATIO OF LIME SULFUR	1–100	1–50	1–33.3	1–25	1–20
Total Sulfur (g. per 100 gal.)	712.600	1828.200	2938.600	4063.700	5196.400
Sulfide Sulfur (g. per 100 gal.)	639.500	1654.400	2680.600	3732.900	4772.800
Thiosulfate Sulfur (g. per 100 gal.)	69.300	143.600	232.600	308.800	403.500
Sulfate Sulfur (g. per 100 gal.)	22.700	30.200	25.400	22.000	20.100
Calcium (g. per 100 gal.)	245.400	552.600	868.400	1186.300	1502.700
Soluble As_2O_5 (g. per 100 gal.)	16.500	15.300	14.800	15.000	14.700
Residue (g. per 100 gal.)	1822.500	1864.100	1842.700	1872.700	1831.600
Sulfide Sulfur (per cent)	89.740	90.490	91.220	91.860	92.040
Mol Ratio S/Ca (as sulfide)	4.883	4.864	4.848	4.831	4.867

* The first figure represents quarts of lime sulfur concentrate; the second, pounds of lead arsenate; the third, pounds of slaked lime; the fourth, pounds of dried skim milk; all figures are on the basis of 100 gallons of spray mixture.

residue resulted. Hydrogen sulfide was not evolved in detectable quantities from any of the mixtures to which lime had been added. Arsenic rendered soluble in the solution was reduced as the quantity of lime was increased.

From the standpoint of the chemical stability of the solution under the conditions of the experiments, the addition of 8 ounces of lime was sufficient to prevent a reaction resulting in the formation of lead sulfide in the residue. The addition of lime did not prevent the decomposition of the sulfides in the solution in a manner proportional to the amount added. The use of lime in quantities of 8 ounces, 1, 2 and 3 pounds aided in the decomposition of the sulfides as the quantity was increased. However, the addition of lime in larger quantities of 6 and 9 pounds reversed the reaction and returned the sulfide content of the solution to a level approximating that of lime sulfur solution at a similar concentration.

Triple mixtures containing lime in quantities of 8 ounces, 1, 2 and 3 pounds contained quantities of polysulfide sulfur nearly as great as lime sulfur solution alone. No apparent loss was found in the total sulfur which was added to the mixture in the form of lime sulfur solution. The addition of lime in all cases prevented a decomposition similar to that shown in the analysis of the solution from lime sulfur and lead arsenate mixtures.

EFFECT OF ADDED DRY SKIM MILK POWDER.—The use of casein in spray mixtures has been advocated by many workers. Various preparations have been used, including liquid whole, condensed or skimmed milk, dried milk powders, and combinations of milk preparations with lime, loosely termed "casein-lime" or calcium caseinate. It apparently has been the general opinion that these materials act in two ways: through their colloidal properties as wetting, spreading and sticking agents, or through means not so clearly understood as preventives of the formation of undesirable decomposition products.

While it is beyond the scope of this paper to investigate the possible action of casein on the physical properties of spray

Table 7.—Variation of the constituents of solution upon the addition of dried skim milk to mixtures of lime sulfur and lead arsenate diluted 1–50.

PROPORTION	8–0–0–0*	8–3–0–0	8–3–0–½	8–3–0–1	8–3–0–2	8–3–0–3
Total Sulfur (g. per 100 gal.)	2244.200	1765.300	1795.200	1828.200	1835.100	1854.300
Sulfide Sulfur (g. per 100 gal.)	2106.800	1576.400	1627.800	1654.400	1658.500	1671.100
Thiosulfate Sulfur (g. per 100 gal.)	124.800	145.400	135.300	143.600	151.300	166.000
Sulfate Sulfur (g. per 100 gal.)	15.200	43.500	32.100	30.200	25.300	17.200
Calcium (g. per 100 gal.)	650.800	543.200	545.400	552.600	548.600	549.900
Soluble As_2O_5 (g. per 100 gal.)		12.100	14.500	15.300	16.200	16.400
Residue (g. per 100 gal.)		1978.800	1764.600	1864.100	1963.600	2120.300
Sulfide Sulfur (per cent)	93.870	89.290	90.660	90.490	90.380	90.120
Mol Ratio S/Ca (as sulfide)	4.755	4.952	4.835	4.864	4.906	4.918

* The first figure represents quarts of lime sulfur concentrate; the second, pounds of lead arsenate; the third, pounds of slaked ime; the fourth, pounds of dried skim milk; all figures are on the basis of 100 gallons of spray mixture.

mixtures, the effect of dried skim milk powder on the chemical composition of mixtures containing lime sulfur and lead arsenate was studied. Mixtures of lime sulfur, diluted within the range of 1–10 and 1–100, were prepared according to the standard procedure. Lead arsenate was added at the rate of 3 pounds and dried skim milk at the rate of 1 pound in 100 gallons of solution. The results are shown in table 6.

nate. The addition of dried skim milk slightly increased the quantity of total sulfur retained in the solution while the sulfide concentration appeared to vary only slightly over the entire range of addition of the dried skim milk.

Comparisons between the analyses of solutions from mixtures of lead arsenate and lime sulfur containing lime and those containing dried skim milk in similar quantities indicate that lime was of

Table 8.—Effects of the addition of lime and dried skim milk upon the constituents of mixtures of lime sulfur and lead arsenate diluted 1–50.

PROPORTION	8-0-0-0*	8-3-0-0	8-3-½-½	8-3-½-1	8-3-½-2	8-3-½-3	8-3-1-½	8-3-1-1	8-3-1-2
Total Sulfur (g. per 100 gal.)	2244.200	1765.300	2243.600	2240.600	2243.700	2245.200	2247.600	2245.300	2245.400
Sulfide Sulfur (g. per 100 gal.)	2106.800	1576.400	1958.200	1847.600	1798.600	1710.600	1863.700	1950.200	1904.600
Thiosulfate Sulfur (g. per 100 gal.)	124.800	145.400	127.900	255.300	315.400	409.400	231.600	130.500	200.400
Sulfate Sulfur (g. per 100 gal.)	15.200	43.500	155.500	137.700	129.700	125.200	152.300	164.600	140.400
Calcium (g. per 100 gal.)	650.800	543.200	804.800	812.700	833.600	852.600	838.700	836.600	852.700
Soluble As_2O_5 (g. per 100 gal.)		12.100	6.400	7.300	9.900	12.600	6.000	6.300	6.600
Residue (g. per 100 gal.)		1978.800	1331.500	1454.700	1468.600	1536.800	1512.800	1640.200	1682.900
Sulfide Sulfur (per cent)	93.870	89.290	87.280	82.460	80.160	76.630	82.920	86.850	84.820
Mol Ratio S/Ca (as sulfide)	4.755	4.952	4.612	4.700	4.744	4.857	4.625	4.421	4.312

PROPORTION	8-3-1-3	8-3-2-½	8-3-2-1	8-3-2-2	8-3-2-3	8-3-3-½	8-3-3-1	8-3-3-2	8-3-3-3
Total Sulfur (g. per 100 gal.)	2246.200	2239.700	2241.800	2246.700	2240.600	2246.500	2247.600	2242.200	2245.900
Sulfide Sulfur (g. per 100 gal.)	1834.900	1803.500	1842.100	1946.300	1872.300	1765.600	1801.700	1920.400	1939.200
Thiosulfate Sulfur (g. per 100 gal.)	276.000	212.800	235.100	136.600	242.700	260.200	197.200	164.600	142.600
Sulfate Sulfur (g. per 100 gal.)	135.300	223.400	184.600	163.800	125.600	220.700	248.700	157.200	164.100
Calcium (g. per 100 gal.)	864.800	884.700	896.800	902.500	917.600	918.600	923.300	925.700	928.700
Soluble As_2O_5 (g. per 100 gal.)	7.800	5.700	7.400	5.300	8.400	4.100	4.200	4.600	4.500
Residue (g. per 100 gal.)	1784.700	1998.600	2092.700	2114.600	2146.800	2226.500	2312.100	2484.700	2541.700
Sulfide Sulfur (per cent)	81.760	80.520	82.610	86.630	83.560	78.430	80.110	85.340	86.140
Mol Ratio S/Ca (as sulfide)	4.384	4.072	4.453	3.972	3.842	4.598	4.604	3.832	3.790

* The first figure represents quarts of lime sulfur concentrate; the second, pounds of lead arsenate; the third, pounds of slaked lime; the fourth, pounds of dried skim milk; all figures are on the basis of 100 gallons of spray mixture.

The primary influence of the addition of dried skim milk was a diminution of the decomposition of the solution. The sulfide concentration was greater than that found in similar mixtures containing lime sulfur and lead arsenate. The protection from decomposition of the sulfide sulfur in the solution was not as great as that found when lime in the quantities used was added to like dilutions of the mixture.

Oxidation of the lime sulfur solution was retarded, as shown by the reduced quantities of thiosulfate and sulfur as the sulfate in solution.

A series of mixtures was prepared containing lime sulfur, diluted 1–50, lead arsenate at the rate of 3 pounds and dried skim milk in quantities varying between 8 ounces and 3 pounds in 100 gallons of solution. The results are shown in table 7.

The analyses of the solutions showed results similar to those of the previous experiment. Sulfide sulfur was retained above the value calculated to be present in mixtures of lime sulfur and lead arsegreater benefit in the retention of total and of sulfide sulfur in the solution.

Soluble arsenic in the solutions containing dried skim milk was increased as the proportion of dried skim milk was increased. This has been explained by Goodwin & Martin (1925) and by Thatcher & Streeter (1924) as due to the retention of hydrogen sulfide by the casein in solution. The continued increase of soluble arsenic in solution on addition of larger quantities may be explained by assuming that the arsenic acid formed in the reaction will further react upon the lime sulfur solution, causing the release of more hydrogen sulfide.

QUADRUPLE MIXTURES CONTAINING LIME SULFUR, LEAD ARSENATE, LIME AND DRIED SKIM MILK.—Table 8 shows the analyses of mixtures containing various quantities of lime and dried skim milk when added to a standard preparation of lime sulfur, diluted 1–50, and lead arsenate in the proportion of 3 pounds in 100 gallons of solution. All of the mixtures

were prepared according to the standard procedure and the solid materials added in the proportion of pounds in 100 gallons as indicated.

The addition of dried skim milk to the mixture containing 8 ounces of lime reduced the sulfide content of the solution. As the proportions were increased through 1, 2 and 3 pounds, the sulfide sulfur in the mixture continued to decrease, with a total loss in percentage of approximately 12 per cent. The mixtures containing equivalent quantities of lime and dried skim milk showed the best retentive power in respect to the sulfide sulfur in solution. The protective action of the lime in the prevention of the formation of soluble arsenic was retarded by the addition of dried skim milk, and the soluble arsenic found in the 8–3–½–3[4] mixture was similar to that found in the double mixture of lime sulfur and lead arsenate. The molecular ratio of sulfur to calcium, indicating the condition of the polysulfides in the solution, was increased as the proportion of dried skim milk was increased in the mixture.

Similar results were shown in analyses of mixtures containing various proportions of skim milk in the dry form to the mixture of lime sulfur, lead arsenate and 1 pound of lime. However, the addition of 8 ounces of skim milk powder was less effective in this mixture than 1 pound. Mixtures containing 2 and 3 pounds of dried skim milk to 1 pound of lime showed a decrease in the sulfide concentration below that found in solutions made from mixtures containing equal quantities of lime and dried skim milk. The protective influence of lime with respect to the soluble arsenic formed in the mixtures was only slightly interfered with by the addition of dried skim milk in quantities of 8 ounces, 1, 2 and 3 pounds. The ratio of sulfur to calcium in the sulfide form as calculated on the solutions decreased as the quantities of dried skim milk was increased.

Analyses of the mixtures containing lime sulfur, lead arsenate and 2 pounds of lime with varying proportions of dried skim milk are also shown in table 8. The results with this series of mixtures were similar to those of the previous experiments, with the exception that the addition of dried skim milk in proportions of 8 ounces, 1 and 2 pounds increased the retention of the sulfide concentration of the mixtures with the 8–3–2–2 mixture, showing the maximum retention of the sulfide concentration. The mixtures containing 3 pounds of dried skim milk showed a decrease in the sulfide percentage when compared to 8–3–2–2 mixture.

The mixtures prepared with 3 pounds of lime and varying quantities of dried skim milk (table 8) showed a continuous increase in the percentage of sulfide sulfur in solution as the amount of dried skim milk was increased in the proportion of 8 ounces, 1, 2 and 3 pounds with the 8–3–3–3 mixture showing the maximum retention of the sulfide concentration.

Table 9.—Percentage sulfide concentration in triple and quadruple mixtures containing lime sulfur, diluted 1–50, three pounds of lead arsenate and various proportions of lime and dried skim milk in 100 gallons of solution. Calculations are based on the total sulfur added to the solution. Lime sulfur solution, diluted 1–50, showed a sulfide concentration of 93.87 per cent.

Pounds Lime	Pounds Dried Skim Milk				
	0	½	1	2	3
0	70.25	72.09	73.73	73.90	74.46
½	88.18	87.25	82.32	80.14	76.22
1	80.01	83.04	86.89	84.86	81.75
2	77.56	80.36	82.08	86.72	83.42
3	76.04	78.67	80.28	85.57	86.40

Table 9 indicates the sulfide concentration found in the various quadruple mixtures, calculated on the basis of the total sulfur added to the solution as lime sulfur solution at a dilution of 1–50. Since the total sulfur in the mixtures containing lime sulfur and lead arsenate and the triple mixtures containing lime sulfur, lead arsenate and dried skim milk was reduced by precipitation of sulfur from the solution, the sulfide concentration as indicated in table 9 for these mixtures is less than those calculated in tables 3 and 7.

On the basis of the sulfide concentration of the solution, a mixture of the proportion of 8–3–1–3 was just as effective as a mixture containing the components in proportion of 8–3–3–1. However, the former mixture indicated a greater ratio of sulfide to sulfide calcium in the solution. If, for other considerations, it is

[4] In the proportions used here and subsequently throughout this paper, the first figure represents quarts of lime sulfur concentrate; the second, pounds of lead arsenate; the third, pounds of slaked lime; and the fourth, pounds of dried skim milk; all figures are on the basis of 100 gallons of spray mixture

desirable to add dried skim milk powder, from the analyses it appeared that the proportion of 8–3–½–½ was the best from the point of view of the retention of the sulfide concentration, the lowering of the amount of soluble arsenic in solution and prevention of formation of large quantities of residue precipitated from the quadruple mixtures. However, the proportion 8–3–3–3 produced a relatively small amount of soluble arsenic with a relatively large amount of sulfide sulfur.

COMPARISON OF VARIOUS COMBINATIONS.—To facilitate comparison, the various combinations investigated in this study have been arranged in the form of two charts (figs. 3 and 4), in which the amounts of polysulfide sulfur (as per cent of the total sulfur present) and the soluble arsenic (as grams per 100 gallons of spray mixture) are shown.

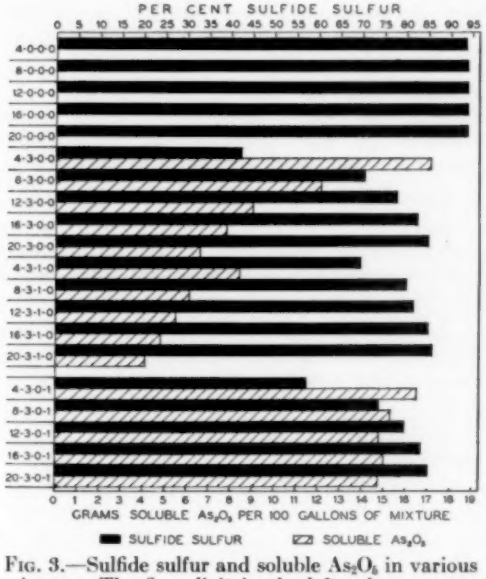

FIG. 3.—Sulfide sulfur and soluble As_2O_5 in various mixtures. The first digit in the left column represents quarts of lime sulfur concentrate; the second, pounds of lead arsenate; the third, pounds of slaked line; and the fourth, pounds of dried skim milk; all figures are on the basis of 100 gallons of spray mixture.

In considering the data presented in these figures, it is interesting to note that Swingle (1929) found that a concentration of As_2O_5 in a spray mixture equivalent to approximately 4.5 grams (0.0012 per cent) per 100 gallons did not injure peach foliage, but that 5.7 grams (0.0015 per cent) of As_2O_5 per 100 gallons caused slight leaf burning on peach foliage. The apple is considered more resistant to arsenical injury than the peach, so presumably the limits would be higher for this fruit.

It should be pointed out that in the quadruple mixtures, which are shown in the last four groups of fig. 4, the general effect on the percentage of polysulfide sulfur of the various proportions seemed to be rather slight, with variations only from

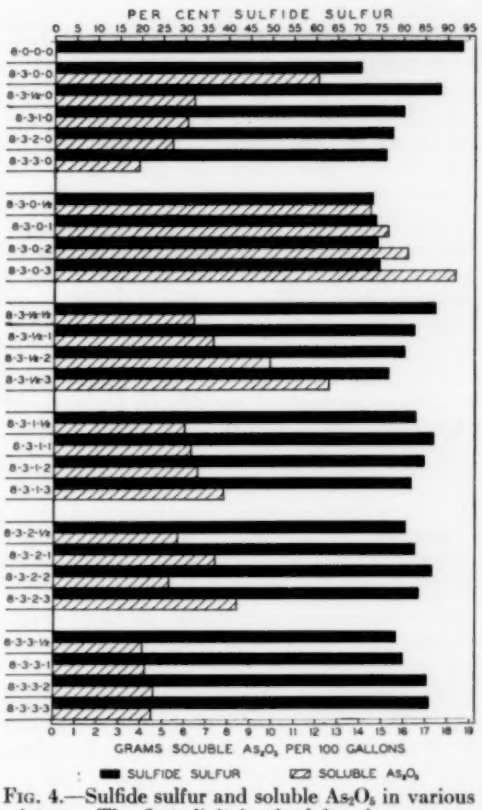

FIG. 4.—Sulfide sulfur and soluble As_2O_5 in various mixtures. The first digit in the left column represents quarts of lime sulfur concentrate; the second, pounds of lead arsenate; the third, pounds of slaked lime; and the fourth, pounds of skim milk; all figures are on the basis of 100 gallons of spray mixture.

87.5 to 77.0 per cent, although the consistent differences within each group are to be noted. The maximum amounts found are the same within the experimental error, and appeared in mixtures with the proportions 8–3–½–½; 8–3–1–1; 8–3–2–2 and 8–3–3–3. These are the mixtures in which the lime and skim milk powder were in equivalent amounts. The soluble arsenic, on the other hand, showed

rather wide variations, the minimum amounts (within the limits of the experimental error) being found in the mixtures with the proportions 8–3–3–½; 8–3–3–1; 8–3–3–2 and 8–3–3–3. The difference between the amounts of soluble arsenic in these mixtures and that found in the 8–3–½–½ combination is slight, and probably not significant from a practical standpoint when such mixtures are used on apple trees. This is of considerable practical importance when the cost of materials is to be considered.

CONCLUSIONS.—Over a one hour period, lime sulfur solution was stable toward oxidation in solutions more concentrated than 1–100. The solutions contained quantities of soluble sulfur, the amount of which depended upon the dilution of the concentrate.

A period of 45 hours was necessary for the decomposition of the sulfide sulfur in a lime sulfur solution diluted 1–50. Thiosulfates and sulfur as the sulfate were formed in solution as the sulfide disappeared.

Distilled water used as the diluent gave the most consistent results on analysis of the lime sulfur solution, but in general any of the waters tested may be used for dilution without change in the soluble sulfur in solution.

Decomposition of lime sulfur by the addition of lead arsenate was found to be greater in the dilute mixtures than in the concentrated. In solutions more concentrated than 1–50, the decomposition appeared to be a constant quantity.

The effect of a change in temperature upon the decomposition of lime sulfur by lead arsenate appeared to be only as an alteration of the rate of decomposition.

Arsenic appeared to be rendered soluble in the solution; the amount of which was relative to the quantity of hydrogen sulfide evolved from the solution.

Lime added to mixtures of lime sulfur and lead arsenate prevented the decomposition of the sulfide sulfur of the solution. The arsenic in solution was decreased as the proportion of lime was increased. Residues resulting from the addition of 1 pound of lime to the diluted mixtures of lime sulfur and lead arsenate between the range of 1–20 and 1–100 were constant. The reduction in weight of the residue approximated the weight of lead sulfide present in residues from mixtures of similar dilution containing lime sulfur and lead arsenate.

Progressive increase in the proportion of lime added to a 1–50 dilution of lime sulfur and lead arsenate showed a varied effect upon the percentage of sulfide sulfur in solution. When 8 ounces of lime were added, a protection from decomposition of the sulfide resulted which was not equaled by any quantity used until 9 pounds of lime were added. The condition of the sulfides with respect to calcium in combination in solution was decreased as lime was added to the mixture.

Dried skim milk in combination with the lime sulfur and lead arsenate aided in the retention of the sulfide sulfur content of the solution. The retardation of the decomposition was not as great as that afforded by lime. Soluble arsenic was formed in the solution in quantities greater than those found in solutions from lime sulfur and lead arsenate mixtures.

Quadruple mixtures containing lime sulfur, lead arsenate, lime and skim milk in the dry form in proportions of 8 ounces, 1, 2 and 3 pounds in 100 gallons of solution showed a protection from decomposition of the sulfides, the amount of which depended upon the proportion of lime and dried skim milk that was present in the mixture.

A compilation of the percentages of sulfide sulfur found to be present in the solutions from the quadruple mixtures indicates that mixtures containing equivalent quantities of both lime and dried skim milk will give the greatest protection to the lime sulfur from decomposition by lead arsenate. The percentage of sulfide sulfur, however, did not attain the values found in solutions of lime sulfur at the same concentration.—3-18-38.

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SCIENTIFIC NOTES

Nicotine Sulphate Plus Summer Oil for the Control of Tentiform Leaf Miners

Various tentiform leaf miners have been noticed in sporadic outbreaks from time to time in Michigan orchards. Generally, the damage inflicted has been more apparent than real.

In September, 1936, my attention was called to an unusually severe outbreak of *Ornix geminatella* Pack. The orchard was kept under observation and the 1937 infestation started to develop in May. Severe defoliation seemed imminent before the season was over.

A spray of nicotine sulphate 40 per cent, three-fourths pint with one-half gallon summer oil emulsion, cleaned up the infestation, penetrating the mines and killing the caterpillars. Counts indicated a kill in excess of 90 per cent.—2-8-38.

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Flea Beetle Injury to Sugar Beets in Central Utah

During the spring of 1937 the hop flea beetle, *Psylloides punctulatus* Melsh., bred in enormous numbers upon *Cheirinia repanda* (L.) Link, an introduced wild mustard known commonly as western wallflower, on the range land adjacent to the cultivated areas of the Sevier Valley in central Utah. These range lands, involving the territory which extended from Levan, through Fayette and south to Gunnison, a distance of about 20 miles, produced approximately 9000 acres of *C. repanda* in 1937, as compared to approximately 100 acres during normal years. When this plant matured the flea beetle dispersed to near-by sugar beet fields and caused damage which resulted in nearly total destruction of approximately 1000 acres of sugar beets in the seedling stage in the Sevier Valley.

The cultivated area most severely attacked by flea beetle included approximately 3500 acres of sugar beets in the territory extending southward from Gunnison to Sigurd. The dispersal of the flea beetles from *C. repanda* occurred at a time when the sugar beets were in the cotyledon stage. The feeding of the flea beetle was restricted principally to the cotyledons and later to the tender beet foliage. However, in many instances the cool windy weather which prevailed during the period from late in April to early in June forced the flea beetles to seek shelter at the lower parts of the plants and during their sojourn in this location they fed to some extent on the stem of the sugar beet seedlings below the level of the soil surface.

Associated with the flea beetle population on the sugar beets, there existed a heavy infestation of the beet leafhopper, *Eutettix tenellus* (Bak.), the vector of the curly top disease. The combined attack of these two species of insects, plus subnormal temperatures and dessicating winds during the early part of the season, were responsible for a marked decrease in the yield of sugar beets in the Sevier Valley during 1937.

Preliminary experiments designed to control the flea beetle indicated that a spray made up at the rate of 1 pound of derris root powder containing 2 per cent of rotenone, in 50 gallons of water, killed a large proportion of the resident flea beetle population. This spray, however, gave only temporary protection, since incoming flea beetles soon reinfested the fields. Bordeaux mixture (4-4-50), to

which was added 4 pounds of calcium arsenate applied at the rate of 75 gallons per acre, gave satisfactory protection against the flea beetles.—2-10-38.

H. E. DORST, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.*

Tobacco Flea Beetle Outbreak

A very serious outbreak of the tobacco flea beetle, *Epitrix parvula* (F.), occurred in several of the Piedmont counties of Virginia and of North Carolina during May and June of 1937. In Virginia the losses were very heavy in three Virginia counties: Pittsylvania, Halifax and Charlotte.

The tobacco flea beetle feeds on tobacco and related plants throughout the summer, but generally

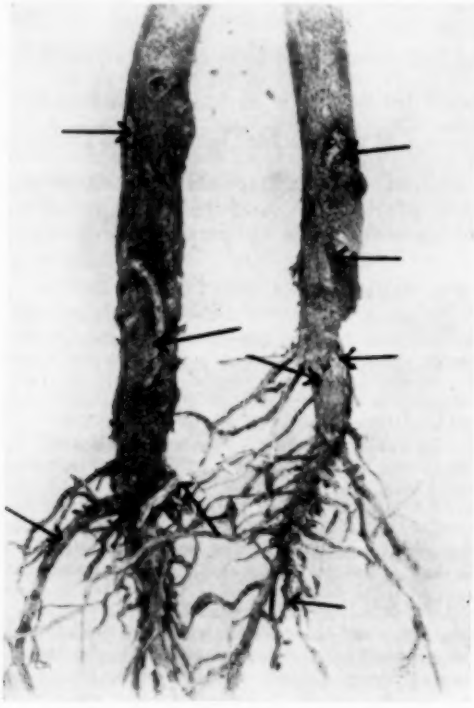

FIG. 1.—Roots and stems of young tobacco plants badly injured by flea beetle larvae. The arrows point to the injured areas. There are many other places on the roots that have been injured but that do not show up in the photograph.

the most serious damage is to young tobacco plants in the seed bed. The adults eat holes in the small leaves, often with serious results to the plants. The flea beetle larvae feed on the roots and stems of the plants both in the seed bed and in the field, but the larvae are so small that the injury they cause is usually not associated with flea beetle.

The season of 1937 was unusual. There was an abundance of rain, and the downy mildew disease of tobacco, *Peronospora tabacina*, caused serious losses. All plant beds were injured more or less. About two weeks were required for the plants to outgrow the injury by this disease. Notwithstanding the combined injury by the downy mildew and the flea beetle, many tobacco seedlings were produced.

Transplanting started about May 10 as usual, but the plants failed to grow after being set in the field, and in a few days many of them died. It was believed by growers that the plants were dying as a result of injury by blue mold, and the fields were reset. In Pittsylvania County many fields had been reset five times by June 15. At that time a brief visit was made to the tobacco section and there were still some fields with only a partial stand. Then it was learned that the stems and roots of the plants were being injured by the flea beetle larvae, fig. 1. Many of the fibrous roots had been eaten away, and frequently 10 or 12 mature larvae were found in the stems of some plants. It is evident that large numbers of flea beetle eggs were deposited about the plants while they were still in the seed bed and that in the interval required for the plants to recover from the blue mold attack the eggs hatched and the larvae entered the stems. The plants were so badly infested when transplanted that many died within 10 days after being set in the field. The process of resetting continued until all plants available had been used and a few growers made long trips to secure additional plants.

Field studies showed that some plants were killed or held back by downy mildew and some were damaged by the improper use of fertilizer, but all plants showed some injury by flea beetle. As a result of the downy mildew and the flea beetle, the crop in the area affected was reduced about 20 per cent. A few crops were plowed up. It was not possible to determine what part of the damage was caused by flea beetles. A few growers in different sections not only made protective sprays for downy mildew but also treated the tobacco seedlings for the flea beetle. Unfortunately there were only a few who did this, but the crops in fields in which treated plants were used were outstanding. These few fields usually had a good stand of uniform plants. The fields in which untreated plants were used generally had an imperfect stand, although they had been reset frequently.

While it is common knowledge that the flea beetle larvae feed on the roots and stems of tobacco plants, such serious injury as occurred in the 1937 season has not been previously observed in this state.—1-7-38.

W. J. SCHOENE, *Virginia Agricultural Experiment Station, Blacksburg.*

Identity of the Common Species of American *Trichogramma*

When Peterson (1930) definitely proved the existence in America of two species of *Trichogramma* he stated that he made no attempt to ascertain their correct scientific names.

Since it appeared to Peterson that Riley (1871, 1879), who described a dark colored species as "*minutum*" and a yellow species as "*pretiosum*," may have had the same species in Missouri that Peterson found in New Jersey, he suggested for the sake of convenience that Riley's original specific names be used to distinguish these biological color species.

Therefore these names have generally been used by the writer and others to designate the dark and

light colored species of the common American *Trichogramma*. However, Peterson stated that " . . . it should be noted that Riley's *Trichogramma minuta* material was collected in the fall, and it is possible that he may had the dark colored individuals of the yellow species." It now appears that such was the case.

Under laboratory conditions the species of *Trichogramma* are readily distinguished by differences in color and developmental rates. Such biological differentiation usually is not possible in the field. However, *Trichogramma*, as in the case of a number of other parasites, prefers certain habitats and its natural hosts are those that are found in such habitats. Under natural conditions, therefore, the number of species attacked is limited by habitat.

Authentic data, assembled to date, show that only the yellow species persists in arboreal habitats and only the dark species in field or low shrub habitats. These habitats are characterized by different host species.

Riley reared his dark *minutum* from the eggs of *Basilarchia archippus* collected on willow in the fall of the year. Later Packard (1880) described a yellow species reared, June 30, by S. H. Scudder from *Papilio turnus* as *Trichogramma minutissimum*. According to Howard (1889), Scudder reared additional specimens from *Basilarchia archippus*, the color of which during life was wax-yellow. It is apparent therefore on this basis that *T. minutissimum* is the summer phase of *T. minutum*.

On the other hand, *Trichogramma pretiosum* was described from the eggs of *Alabama argillacea*, a field host. Girault (1906) studied this species as a parasite of *Heliothis obsoleta* and found that, as the season became colder, black individuals appeared. This dark fall phase he described as *nigra*, a variety of *T. pretiosum*.

We have therefore gradations in color both in the arboreal species and in the field species. However, under natural conditions *pretiosum* does not entirely lose its dark markings while *minutum* does. The writer has examined many specimens from field hosts but has never observed any that were pure yellow. Both species may include many races characterized by differences in rates of development.

The seasonal phases of the two common species of *Trichogramma* should be designated as follows:

SPECIES	SUMMER PHASE	SPRING OR FALL PHASE
Arboreal	*T. minutissimum*	*T. minutum*
Field	*T. pretiosum*	*T. nigra*

—2-14-38.

S. E. FLANDERS, *University of California Citrus Experiment Station, Riverside.*

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The pyralid moth, *Lineodes integra* Zell., as a Pest of Eggplant

The account by Compton (1937) of this insect as a pest of tomatoes recalled an observation by the writer made several years ago. On October 12, 1931, he noted that a small patch of eggplant in the lower Tia Juana Valley in San Diego County, Calif., was being damaged by larvae which, from the nature of their work and their appearance, seemed to be the greenhouse leaf tyer, *Phlyctaenia rubigalis* (Guen.). Some of these larvae were collected and reared at Alhambra. On emerging the adults were very different from those of the greenhouse leaf tyer. Specimens sent to Washington were identified as *Lineodes integra* Zell. J. E. Graf, formerly in charge of the division of Truck Crop Insect Investigations of this Bureau, wrote as follows regarding the insect: "I find in looking up the literature that this is apparently not an economic species. Its food plants are recorded as *Solanum radula* and *S. jasminiolium*. Apparently the eggplant is a new food."

Several visits were made to the same area in succeeding years, but no more infestations were found. On August 18, 1937, however, J. C. Elmore, when examining tomato plants near Laguna Beach, Orange County, collected folded leaves containing larvae which the writer suspected were this same species. Adults emerged on September 2, 1937, and were easily identified by their striking appearance and characteristic pose. Laguna Beach is about 85 miles north of the Tia Juana infestation, and both are near the seashore.

This species has been taken in Florida, Missouri, Texas, California, Mexico, Colombia, Brazil, Cuba, Jamaica and Grenada (Walsingham 1909–1915).

According to Keifer (1937) this pyralid has been generally distributed in California for a number of years.

He says: "The larvae of this moth have several broods a year on both *Solanum xantii* and *S. umbelliferum*. The young larvae begin by producing a characteristic skeletonization but later become leaf rollers. Tomato is occasionally attacked. A colony of these larvae was found near Cloverdale in 1926, on *Nicotiana glauca*, tree tobacco. I have not observed the larva on *Solanum nigrum*. . . . The moth occurs throughout the valleys and in the coastal section of California, but seems commoner to the south."

John A. Comstock, in a letter written in September, 1937, reports specimens from Santa Catalina Island, Los Angeles and Beverly Terrace, Calif., and Oracle, Ariz.

In a communication in September, 1937, E. P. Van Duzee reported specimens from San Diego in 1915, Cuyamaca Mountains in 1915, Cloverdale in 1926, Exeter in 1924 and Mokelumne Hill, Calif., and Brownsville, Tex. The most interesting specimen is from "Potato Canyon," Calif., collected by W. G. Wright in 1889.

Compton (1937) reports that in Illinois the insect

Table 1.—Life history of *Lineodes integra* Zell. on eggplants at Alhambra, Calif. 1931–32.

Generation	Females Emerged		Eggs Laid		Eggs Hatched	Pupated	Adults Emerged
	Date	Number	Date	Number			
First	Oct. 29–Nov. 2	4	Nov. 3	12	Nov. 9–10	Jan. 25–31	Mar. 21–31
			Nov. 5	56	Nov. 10–12		
			Nov. 10	122	Nov. 13–17		
			Nov. 17	15	—		
Second	March 22	2	Mar. 29	12	Apr. 11	May 31–June 2	June 20–23

has been observed only in greenhouses, but may have migrated from outdoor plants.

With this general distribution the insect could become a pest of considerable importance should conditions become favorable. Either the climate has not been favorable for rapid multiplication or natural enemies have held it in check. The damage to the eggplant observed in San Diego County and the severe damage to tomatoes in greenhouses described by Compton indicate that the insect has possibilities of becoming a serious pest of these plants, and possibly other Solanaceae.

Damage to eggplant is similar to that described by Compton to tomato. The young larvae at first skeletonize the leaves, then as they grow larger they eat irregular holes in the leaves and finally they tie and roll the edges over in typical leaf roller manner. Young caged plants may be severely injured by only a few larvae.

A few observations were made on the life history of this insect on eggplant. From larvae pupating about October 22, adults emerged and were confined in cages over small eggplants.

The data in table 1 show two generations from November 3 to June 20, the winter generation requiring 138 days and the spring generation 83 days. As the developmental period for the spring generation was so much shorter than that for the winter generation, it seems probable that there would be two more generations during the remainder of the year. Four females produced a total of 205 eggs, an average of slightly over 51 each. These were laid in about equal numbers on the upper and lower sides of the leaves; a few were laid on the buds and petals.—4-15-38.

ROY E. CAMPBELL, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.*

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Reaction of the Codling Moth to Nicotine Exposed in Apple Trees

To pursue further the idea of killing the codling moth with nicotine vapor, experiments were made to determine the effect of nicotine exposed to normal evaporation in apple trees. The trees were approximately 15 feet in spread and height, and were rather light in the amount of foliage. A bait jar was placed near the top of each tree. Six small screen cages, each containing two moths, were suspended through each tree. Strips of lightweight muslin, 1½ inches wide and 30 inches long, carrying the nicotine, were evenly spaced among the cages. Each strip carried one-half ounce of 50 per cent free nicotine. A six-ounce, wide-mouthed bottle, in which were placed four screws to facilitate distribution, was used in applying the nicotine. One-half ounce of nicotine was placed in the bottle, the strip was inserted and the bottle was stoppered and vigorously shaken.

The cages and strips were placed in the trees at 6 p.m., and the observations as to final results were made 22 hours later. Three trees were used in each test, the third tree serving as a control. Two series of tests were made, the one on Tuesday and the other on Wednesday of the same week. The results of the tests are indicated in table 1.

Table 1.—Results of two series of tests made to determine reaction of codling moth to nicotine.

Number of Strips Per Tree	Tree 1		Tree 2		Tree 3 (Control)	
	Moths Caught in Bait Jar	Dead Moths in Cages	Moths Caught in Bait Jar	Dead Moths in Cages	Moths Caught in Bait Jar	Dead Moths in Cages
	Experiment 1					
2	8	1	11	2	6	2
4	9	5	3	3	10	1
6	6	8	7	6	10	2
	Experiment 2					
2	4	2	7	1	3	2
4	5	4	6	2	3	2
6	12	12	4	10	8	1

There appears to be no significant correlation between the presence of the nicotine and the number of moths caught in the bait jars. The mortality of the moths in the cages was apparently not affected by two strips to the tree, but a marked mortality resulted from four strips to the tree, and a mortality approximating 80 per cent resulted where there were six strips to the tree. The maximum temperature on the day of experiment 1 was 99 degrees F. and on the day of experiment 2 it was 103 degrees F. Scarcely any odor of nicotine could be detected when the strips were held to the nose at the end of 24 hours. There was an appreciable

breeze from sunrise until sunset on both days, but at times during the night the atmosphere was practically dead calm.—4-25-38.

RALPH H. SMITH, *University of California at Los Angeles.*

New Control Methods for the Corn Ear Worm

Outbreaks of the corn ear worm *Heliothis obsoleta* (F.) in the northern states during recent years have given impetus to the search for a means of protecting corn ears against attack by this insect. From experiments conducted by the writer during the past three summers in the vicinity of New Haven, Conn., and three winters in Dade County, Fla., two promising methods of protecting corn ears have been developed, fumigation and oiling.

Fumigation of the growing ear is accomplished by inserting a tablet containing hexachlorethane and confining it with a wire clip. The tablets are cylindrical in form, flat at one end and round at the other, about 5 mm. in diameter, and each contains about 0.5 gram of the fumigant pressed with suitable carrier. The clips are made by bending 5-inch lengths of 16-gage galvanized crimping wire in the form of a hairpin, the two members being parallel and in contact and the terminal quarter inch of one being bent at right angles so that the other end, when lifted over it, will catch and hold.

The tablet is inserted in the tip of the ear and pushed in for an inch or more with a pusher consisting of a 1¼ inch length of one-eighth inch wire mounted radially on a metal finger ring. Use of the pusher leaves both hands of the operator free to handle the tablets and clips. As soon as the fumigant is in place, a clip is fastened about the tip of the husk. The evaporating hexachlorethane permeates the silk, killing both the larvae that have entered previous to treatment and those that enter later. The clip prevents the tablet from being pushed out of the ear and confines the hexachlorethane gas. Ears to be protected should be treated as soon as they have become fertilized, *i.e.*, when the silks have wilted but before they have turned brown.

The control obtained by this treatment has consistently amounted to more than 90 per cent of uninjured and uninfested ears in localities where all untreated ears were infested and injured. The fumigant does not injure the ears, and no taste or odor remains on the kernels at the time of harvest. Their suitability as food as in no way affected. As near as can be determined previous to commercial manufacture of the tablets and clips, the total cost of protecting ears by fumigation in this manner, including materials and labor, should be about three cents a dozen.

A much less expensive, though somewhat less efficient, means of protecting corn ears is the application of a light, highly refined mineral oil of 100 to 200 Saybolt viscosity (100 degrees F.) to the silks as soon as the ears have been fertilized. The oil may be atomized or sprayed on the external silks, or it may be applied with an ordinary oil can. The use of the oilcan makes expensive equipment unnecessary and reduces run off. The snout of the can is placed at the tip of the ear or inserted slightly into the silk. From 0.5 to 1 cc. per ear is sufficient to protect it. Oil of the viscosity specified permeates the entire mass of internal silk. Small larvae that entered previous to treatment or that enter later are smothered, and larger larvae usually leave the ears after treatment.

This method of control has resulted in about 75 per cent of uninfested ears, and in as high as 89 per cent of uninjured ears at roasting-ear stage under conditions where all untreated ears were infested and injured. The total cost of this treatment will probably be no more than a cent per dozen ears. The oil is harmless to persons and if applied at the stated rates very little of it reaches the kernels. The marketable attractiveness of roasting ears is in no way affected.

Both these control methods can be applied and will remain effective under any weather conditions. Neither involves the use of expensive or complicated equipment. A single treatment per ear is sufficient. The ears are protected up to the roasting-ear stage or later. There is no danger to consumers of roasting ears as a result of either treatment. Neither one injures the appearance of the ear nor affects its flavor or attractiveness to the consumer.—4-27-38.

G. W. BARBER, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.*

European Parasites of *Rhyacionia buoliana* (Schiff.), *Coleophora laricella* Hbn. and *Phyllotoma nemorata* (Fall.)

Since 1931 the Bureau of Entomology and Plant Quarantine has imported a number of European parasites of the European pine shoot moth, *Rhyacionia buoliana* (Schiff.), the larch casebearer, *Coleophora laricella* Hbn., and the birch leaf-mining sawfly, *Phyllotoma nemorata* (Fall.), for liberation in the United States. Parasites of *Rhyacionia* and *Coleophora* were obtained from Austria in 1931–35, from England in 1936 and from Holland in 1937, and parasites of *Phyllotoma* were obtained from Austria in 1931–34.

Twelve hymenopterous and two dipterous parasites of *Rhyacionia* have been liberated. Three species of these are known to have become established. *Tetrastichus turionum* (Hartig) has been recovered from three colonization points: Brookline, Mass., Matinecock, Long Island, N. Y., and New Vernon, N. J. It has also been reared from material collected at Forest Hills, Mass., about two miles from Brookline. *Cremastus interruptor* Grav. has been recovered from four colonization points: Branford and Fairfield, Conn., Syosset, Long Island, N. Y., and New Vernon, N. J. *Orgilus obscurator* (Nees) was reared from material collected at Newport, R. I., in 1925, which was before these importations were made, but it was not reared again until 1932. Since that time it has been recovered from the following localities: New Haven, Fairfield, Branford, Middletown and Easton, Conn., Syosset, Long Island and North Castle, N. Y., and New Vernon, N. J.

Five hymenopterous parasites of *Coleophora* have been liberated in this country and two have been recovered. *Bassus pumilus* (Ratz.) and *Chrysocharis laricinellae* (Ratz.) have been recovered from liberation points at Sidney, Me., Berlin, N. H., and Saranac, N. Y., and the latter from Sharon, Vt., also.

Five hymenopterous parasites of *Phyllotoma* have been liberated in this country and two have been recovered. *Phanomeris phyllotomae* Mues. has been recovered from colonization points at Bar Harbor and Eustis, Me., and *Chrysocharis laricinellae* (Ratz.) from colonization points at Eustis, Me., and Stark, N. H.

From all the recoveries only a few adult parasites were secured, but in each case both sexes were represented, and in all cases except that of *Cremastus interruptor* the recoveries were made more than one year after the original liberation. *Cremastus* was first recovered in 1937 from liberations made in 1936.—4-11-38.

P. B. DOWDEN and P. A. BERRY, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.*

A Larval Mermithid, *Mermis subnigrescens Cobb, as a Parasite of* the Honeybee*

While making examination of the abdominal contents of crawling bees, *Apis mellifera* L., at the apiary of the University of Illinois at Champaign on June 18, 1937, the writer discovered the presence of a threadlike larva within one worker honeybee's abdomen, the entire contents of which apparently had been consumed by the parasite. The larva, white in color, exhibited some slight wriggling movements when removed but soon became motionless. It measured approximately $1\frac{3}{4}$ inches (43.8 mm.) in length by 1/64 inch (0.4 mm.) in width; its head end was slightly enlarged. The parasitized bee showed no external evidence other than a swollen abdomen and apparent partial paralysis as exhibited by bees suffering from spray poisoning or Nosema disease. Examination of numerous other crawling bees disclosed no further parasites of this nature.

Through the kindness and courtesy of Dr. G. Steiner, Principal Nematologist in Charge of the Division of Nematology, Bureau of Plant Industry, United States Department of Agriculture, whose help is hereby acknowledged, this nematode parasite has been identified as a larval mermithid, the species being *Mermis subnigrescens* Cobb. We quote from his letter as follows: "It is a rather common mermithid species in this country attacking grasshopper species in large numbers; in fact, one of their main controlling agents east of the Rocky Mountains. The finding of this parasite in the honeybee is the first such observation in this country. A closely related species, *Mermis nigrescens*, has been reported as a very rare parasite of the honeybee in Europe."

Finding of this first known case of such parasitism of the honeybee indicates that it may be expected to be found from New England westward to Minnesota, Iowa and Missouri within which area *M. subnigrescens* is known to occur as a parasite of nine species of Tettigoniidae and Acrididae, according to reports of Christie (1937). In the case of grasshoppers, infection results from feeding of the grasshoppers on plants on the surface of which the eggs of this mermithid are laid. Upon being swallowed by the grasshopper the eggs promptly hatch, the larvae entering the body cavity for feeding and growth.

The possible method of infection of a honeybee is in part suggested by the fact the females lay their eggs especially during rainy weather. It is common observation that honeybees, especially after a period of confinement to the hives because of cold weather, often in their eagerness to gather new supplies of water, actually take water from leaves, blades of grass and other objects. Further, it would not be impossible for a honeybee to take nectar that might be contaminated with the eggs of this parasite.

Parasitism of honeybees by another species of mermithid, *Agamermis decaudata*, is not improbable since it is also a general parasite of grasshoppers occurring in practically the same region as *M. subnigrescens* but extending slightly further southward. Since the eggs of *A. decaudata* are laid in the soil, the larvae crawling upward on the plants, the manner of infestation would probably differ from that of *M. subnigrescens* only in that larvae of the former would be swallowed with nectar or water.—4-7-38.

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Methyl Bromide Vapor Against Five Species of Stored Product Insects

In a cabinet of 10 cubic feet capacity, 35 atmospheric fumigations with methyl bromide were made at various room temperatures, concentrations of vapor and periods of exposure. In a typical fumigation, the following reared insects were placed in the cabinet: 100 adult granary weevils, *Sitophilus granarius* (L.); 40 bean weevils, *Acanthoscelides obtectus* (Say); 20 dermestid larvae of several instars, *Trogoderma versicolor* (Creutz); 20 larvae or adults of the square-necked grain beetle, *Silvanus gemmelatus* Duv.; and 20 mature larvae of the dark mealworm, *Tenebrio obscurus* F.

Half of the sample of each species was placed in one vial and half in another. The mouth of each vial was covered with cheesecloth. One set of 5 vials representing the 5 species was placed on the floor of the cabinet, the other was placed in a jar in the cabinet and covered to a depth of 6 inches by wheat. Samples of 20 seeds each of bean, oats, corn and wheat were also placed in the cabinet to test the effect of the vapor on subsequent germination. At the same time a set of vials of insects and a set of seeds were placed in another cabinet of the same size to serve as untreated checks. The desired dose of methyl bromide was applied by pouring a measured volume of the cold liquid into a cold shallow dish on the floor of the cabinet, which was then quickly closed. Mortality counts were made immediately after the insects were removed from the cabinets. As it was noticed that some insects surviving at the end of the exposure period might succumb later from the effects of the vapor, additional mortality counts were made at intervals up to 48 hours.

From the results of the foregoing tests it is estimated that a dosage of 1 pound of methyl bromide per 1000 cubic feet of space should be sufficient to kill 100 per cent of each of the 5 species of insects in

* Contribution No. 192 from the Entomological Laboratories of the University of Illinois.

a 12-hour atmospheric fumigation in a tight vault at temperatures ranging from 58 degrees to 70 degrees F. Of course this is not to be construed as a practical recommendation, as lower dosages may be sufficient or higher dosages required, depending on the species to be controlled and on the quantity and nature of the infested material. The granary weevil was the most susceptible of the five species studied by the writers. Shepard, Lindgren & Thomas (1937) found it more susceptible to methyl bromide than to hydrocyanic acid. In the present work the bean weevil, dermestid larvae, the square-necked grain beetle and the dark mealworm were increasingly more resistant to methyl bromide in the order named.

Under conditions that gave 100 per cent kill of all 5 species of insects, the germination of wheat, oats, corn and beans was not affected by methyl bromide.

Immersion in liquid methyl bromide and exposure to its vapor did not affect any of nine common metals nor change the color of seven wallpapers or of nine samples of dyed cotton goods.

The writers are familiar with the literature on the effect of methyl bromide on man and know that its vapors should not be inhaled. They experienced no ill effects from its use in the present tests and found it non-flammable and easy to handle. On the whole they believe that methyl bromide is worthy of further investigation for the control of stored product insects.

Vapors from the liquids ethylene chlorobromide and tetrahydronaphthalene were also tested in the manner described above, but few tests were made because these compounds appeared to have no practical value against the stored product insects named.—3-7-38.

W. R. PIPER, JR., and R. H. DAVIDSON, *Ohio State University.*

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Furthering the Value of Symposia

AT the recent Indianapolis meetings of the American Association of Economic Entomologists, following the symposium on pea aphid, I made a suggestion that members who are chosen to take part in symposia should arrange previously to have their contributions mimeographed and in the hands of members at the time of registration. In an Association the size of ours, it may not be possible to adopt such a suggestion, but it seems to me something along this line could be considered by those responsible for the program.

Entomologists who are invited to take part in symposia are workers who speak with authority and usually, I would say, occupy positions of importance. It should, therefore, not be difficult in most cases to have copies of contributions prepared, or at least good abstracts of them, so that the average member will have a fair idea of what is under discussion and in this way be in a position to take an intelligent part in the proceedings. Furthermore, such copies would undoubtedly not only assist very materially in advancing investigations in many districts, but would also help those who present reports to their respective departments following attendance at important conferences.

When the World's Poultry Congress was held in London, Eng., in 1930, each delegate on registration was presented with six volumes in which all papers to be read at the several sessions were printed in full. This did not interfere in any way with the presentation of papers by authors at the definite sessions indicated in the program. The arrangements did, however, give those who were specially interested in any paper an opportunity, in the meantime, to think of intelligent questions.

All of us who attend the annual meeting hear only a limited number of papers, but we all derive much benefit from personal contacts and the opportunity thus given of conferring on common grounds. Such opportunity, however, is restricted. After listening to an important symposium, I have frequently had discussions of value with those who took part, but these hurried talks would have been of much more value if I had been given an opportunity beforehand of reading the paper, or a synopsis of it.

ARTHUR GIBSON

More News for Entomologists

EVERY scientific society is, after all, only a conglomerate of human beings. Like most other human beings, entomologists regard with interest the comings and goings of their fellows. They read the newspapers, they exchange bits of news at their clubs, they even listen to the tales their wives bring home from afternoon bridge or tea tables.

One section of the JOURNAL OF ECONOMIC ENTOMOLOGY, "Current Notes," is set aside for news of entomologists. The launching of new projects, the completion of old projects, meetings, awards, election to office in other societies, travel in the interest of special entomological investigations, changes in personnel, promotions, retirements are all legitimate news items for a publication like the JOURNAL.

A few readers of the JOURNAL willingly assume as their responsibility the submission of such items of interest as come to their attention. But unless more readers in widely scattered parts of the country assume a like responsibility, the items will not be representative of American entomology as a whole. Secretaries of branch and special meetings should consider it part of their jobs to submit brief statements of the chief features of these events, both before and after they take place, for publication in the JOURNAL.

At this time, the Editor wishes to urge upon readers the necessity for assuming the responsibility of submitting to the JOURNAL such notes about themselves and their associates as are of general interest to entomologists.

T. H. FRISON

OBITUARIES

William Earl Rumsey 1865-1938

William Earl Rumsey, a pioneer member of the American Association of Economic Entomologists and a charter member of the Entomological Society of America, died of chronic pyelitis, February 16, 1938.

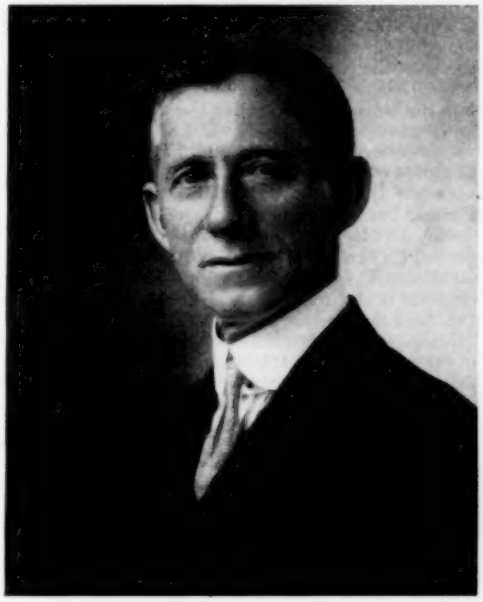
Mr. Rumsey was born in Van Etten, N. Y., on September 9, 1865. He attended Cornell University, where he studied entomology under Professor Comstock and from which he was graduated in 1891. On January 9, 1893, he became assistant to Dr. Hopkins at the West Virginia Experiment Station and later became entomologist of the station. At the time of his death he had completed forty-five years continuous service, being the oldest member of the staff. From 1913 to 1934 he was also State Entomologist.

In his earlier years at the station he participated in the studies of forest insects; later he did much work with fruit pests, particularly with the periodical cicada and the San José scale.

As State Entomologist, Mr. Rumsey won a wide acquaintance with the people of the state while performing tasks which were usually thankless, disagreeable and difficult. Especially was this true in the campaign to eradicate cedars in the commercial orchard section for the protection of apples from the rust. He was here faced with a very distinct conflict of interests and it was due almost entirely to his personal characteristics that the work was established without lasting resentment from any group. His quiet perseverance, transparent sincerity of purpose, tact and consideration won him the liking and respect of all with whom he had to deal, and not only led to success in this undertaking, but won much support for the work of the Experiment Station in general.

Mr. Rumsey was in all respects a good citizen; he was active in fraternal work and in the Methodist Church. His many friends in all walks of life testify to his many lovable qualities. He retained his mental and physical activity to the last, and, in spite of his physical handicap, could still play a game of tennis which was beyond most of his younger associates.

Among his colleagues throughout West Virginia University and the entomological profession his cheerful friendliness, interest in others and inflexible support of what was right, coupled with



William Earl Rumsey

charity for the weaknesses and mistakes of others, won him universal love and respect.

Surviving relatives include his wife, Stella Berkshire Rumsey, a son, Neale O. Rumsey, and a daughter, Virginia Rumsey Ney. Two sisters, Mrs. Holley Briggs of Van Etten, N. Y., and Mrs. Annie Agee of Portland, Ore., also survive.—5-4-38.

—L. M. Peiars

Pressley Adams Glenn 1867-1938

P. A. Glenn was born in Westmoreland County, Pa., July 9, 1867. He studied at Highland College and the University of Kansas, receiving the A.B. and honorary A.M. degrees from Highland and an A.B. from Kansas. Following graduation he taught science and mathematics in Highland College from 1898 to 1907, and was Assistant Professor of Entomology in the University of Kansas from 1907 to 1911. He came to Illinois in 1911 and served as Entomologist and Chief Horticultural Inspector with the organization now known as the Natural History Survey, under the administration of Professor S. A. Forbes. In 1917 he was made Chief Inspector of the Division of Plant Industry, Illinois State Department of Agriculture, and held this position, with his office at Urbana, until his retirement in 1935. In this position he demonstrated excellent judgment and a fair but fearless and progressive administration which won the support of the large body of nurserymen with whom he worked

Although his life was largely devoted to inspection and administrative work, he demonstrated research ability of a high order and was outstanding as a field observer of insect life. His most extensive studies dealt with the green bug ("Influence of Climate on the Green Bug and its Parasite," University of Kansas Department of Entomology, 1909) and the codling moth ("Codling Moth Investigations of the State Entomologist's Office, 1915–1917," Illinois Natural History Survey, Bulletin 14, Article 7, 1922).

His death occurred at the home of his son in Ellenwood, Kans., December 9, 1937. He will long be remembered for his contributions to economic entomology and legal control and for his kindliness, sincere friendship, devotion to duty and uncompromising integrity.—4-17-38.

—C. L. Metcalf

CURRENT NOTES

Third Annual Florida Entomological Conference

The Third Annual Florida Entomological Conference was held in Gainesville on March 17, 18 and 19. This is a conference for students and professional entomologists which is sponsored by the Newell Entomological Society.

This year's conference was well attended with some one hundred persons registering during the course of the various sessions.

Dr. Dwight M. DeLong of Ohio State University was the featured speaker for the occasion. Dr. DeLong gave an interesting talk at the smoker on Thursday evening, March 17. On Friday, March 18, he gave a technical paper on leafhopper control.

One of the highlights of this conference was the Fernald banquet which was held in Florida Union Annex on March 18. One hundred three people attended this banquet, which was given in honor of Dr. Henry T. Fernald, Professor Emeritus of Massachusetts State College and now a resident of Florida. Dr. John J. Tigert, President of the University of Florida, and A H. Madden, special representative of the Massachusetts State College, were the featured speakers.

The conference was adjourned at noon, Saturday, March 19, as the assemblage rose in salute to Doctor Herbert Osborn, Professor Emeritus of Ohio State University, on the occasion of his eighty-second birthday.

Retirement of Professor Johanssen

Professor O. A. Johanssen retired from active teaching and from his duties as head of the Department of Entomology at Cornell University in April of this year. On April 30 a testimonial dinner was given in his honor.

Organization Meeting in Georgia

An organization meeting of the Georgia Entomological Society was held in the Aeronautical Engineering Building of the Georgia School of Technology at Atlanta, Ga., on April 1, 1938. A constitution and by-laws were adopted and the following officers were elected: President, Theo. L. Bissoll; Vice President, Paul M. Gilmer; Secretary-Treasurer, Horace O. Lund; Historian, P. W. Fattig.

Following the business proceedings several scientific papers were presented and discussed, together with moving pictures of the white fringed beetle, the Japanese beetle and the potato beetle.

Host to Cotton States Branch

In the spring of 1939, the Newell Entomological Society will act as Florida host to the Cotton States Branch of the American Association of Economic Entomologists. This is the first time in the history of the Cotton States Branch that a student society has served as host. The convention city will be selected at an early date.

Metcalf at Purdue

Professor C. L. Metcalf of the University of Illinois was the principal speaker at the annual banquet of the Thomas Say Entomological Club of Purdue University on March 21. His subject was "An Insect Looks at Mankind."

Jokebook for Entomologists

For entomologists who must occasionally make speeches, as well as for those who do not, *The Entomologists' Jokebook* will prove a source of inspiration and will enable them to see themselves as the world sees them, in a light perhaps less serious than they usually see themselves and each other.

The book is the work of Professor J. J. Davis of Purdue University, President of the American Association of Economic Entomologists. For years he has been collecting jokes, poems and anecdotes relating to entomology. These are now confined within the 160 pages which make up the book. A copy may be secured from Exterminators Log, 512 East 14th Street, Kansas City, Mo. The price is $1.50.

Return of Worthley

Professor H. N. Worthley returned to State College, Pa., on June 1, after nine months in residence at the Ohio State University, Columbus.

Discussion of Insect Problems of the Ever-Normal Granary Program

At the request of Avery S. Hoyt, Acting Chief of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, the official entomologists of a number of the north central states met at the New Hotel Jefferson, St. Louis, Mo., April 19, to discuss the insect problems connected with the ever-normal granary program. Representatives were present from North Dakota, Nebraska, Iowa, Kansas, Minnesota, Missouri, Texas, Ohio, Michigan, Indiana and Illinois.

The principal discussion concerned the damage from insects likely to occur by holding corn in farm cribs, or small grain in farm bins, for a period of one or two years. Certain regulations concerning the handling of grain in farm storage were agreed to by the group. These will be put out later by the Bureau of Entomology and Plant Quarantine.

Dr. P. N. Annand, Special Assistant to the Chief of the Bureau of Entomology and Plant Quarantine, acted as chairman of the meeting.

Pest Control Conference at Purdue

The second Pest Control Operators Conference was held at Purdue University in January. In attendance were 105 persons from 22 states and Canada. Reports are that the conference was so successful that it will be made an annual affair.

Cotton States Branch Meeting

Large attendance and keen interest characterized the meeting of the Cotton States Branch of the American Association of Economic Entomologists at New Orleans, February 3–5. O. I. Snapp was secretary of the meeting.

PEST CONTROL CONFERENCE ON THE PACIFIC COAST

The first Pacific Coast Pest Control Conference was held at Stanford University, Calif., March 28–31. Besides 77 pest control operators from the Pacific Coast, the attendants included Professor J. J. Davis of Purdue University.

PACIFIC COAST BRANCH MEETING

The Pacific Coast Branch of the American Association of Economic Entomologists is scheduled to meet in San Diego, Calif., June 22–24.

HAYDAK ON TOUR

Dr. M. H. Haydak, instructor in entomology and economic zoology, University of Minnesota, St. Paul, on May 17 visited the departments of entomology and physiology of the University of Illinois and the Illinois Natural History Survey at Urbana. He was returning from an extended tour in which he had visited the University of Iowa, Dadant's Bee Culture Plant at Hamilton, Ill., the zoology department of Louisiana State University, the U. S. Department of Agriculture Bee Culture Laboratory as Baton Rouge, La., big producers of queens and package bees in Mississippi, the University of Tennessee and the University of Kentucky. He planned to visit the University of Chicago, Northwestern University and the University of Wisconsin.

INDEX V DISTRIBUTED TO MEMBERS

Several members of the American Association of Economic Entomologists have expressed surprise at receiving copies of Index V when no specific order had been placed. At the Forty-Eighth Annual Meeting in St. Louis, a 50 cent increase in dues was voted to cover the publication of Index V. All members of the Association who have kept their dues up to date since that meeting have been mailed a copy of the index without further charge. All other members may order copies at the price indicated in the advertisement on page vi.

ROCKY MOUNTAIN CONFERENCE OF ENTOMOLOGISTS

The fourteenth Rocky Mountain Conference of Entomologists will be held at the University of Wyoming summer camp, Centennial, Wyo., August 14 to 19, inclusive. As in the past, the arrangements will be such that families of entomologists in attendance can be comfortably cared for at the camp and enjoy an outing while the meetings are under way.

The University of Wyoming summer camp is located in the Medicine Bow National Forest about 40 miles west of Laramie, Wyo., and 100 miles north and west of Fort Collins, Colo., at an elevation of approximately 9500 feet. The camp consists of a large recreation and dining hall, two lecture and laboratory buildings and a number of cabins equipped to accommodate three persons in each cabin. All meals and bedding will be furnished at a reasonable cost at the camp. The Medicine Bow Mountain area is noted for its rugged scenery and good trout fishing. The nearby streams, lakes and mountain meadows furnish excellent high altitude insect collecting.

Reservations should be made well in advance with the Secretary, George M. List, Colorado State College, Fort Collins, Colo. Detailed information in regard to the final arrangements will be sent those indicating they are interested in attending. Topics for discussion should be sent at an early date.

HORTICULTURAL INSPECTION NOTES

THE FEDERAL quarantine regulations relating to the Japanese beetle were revised effective April 11, having as the principal change the extension of regulated area in New York, Pennsylvania, Ohio, Maryland, Virginia and West Virginia, owing to the finding of infestations therein. Some outlying areas where the beetles have been found were not included because of assurance from the states concerned that adequate measures will be taken to prevent the spread of the pest from these areas.

THE BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE has recently approved vacuum fumigation with hydrocyanic acid gas for the treatment of imported broomcorn restricted on account of the European corn borer. Previously such material was enterable subject to steam sterilization as a condition of entry. Recent tests have demonstrated that complete mortality of the European corn borer can be effected when the temperature of the stalks and of the fumigation chamber is not less than 60 degrees F. and when this temperature is maintained during a three hour exposure to hydrocyanic acid gas at the rate of three pounds of liquid hydrocyanic acid or its equivalent per 1000 cubic feet of space with the air pressure in the fumigation chamber reduced to the equivalent of 2 inches of mercury (a 28-inch vacuum at sea level), and held during a three hour period.

FUMIGATION is required as a condition of entry into Arizona from infested states of 44 kinds of plants, chiefly ornamentals, designated as hosts of the red scale, of certain mealybugs and certain whitefles, in revision of Arizona quarantine order No. 4 adopted March 17. The states designated as infested are Alabama, Arkansas, California, Florida, Georgia, Louisiana, Mississippi, New Mexico, North Carolina, South Carolina, Tennessee and Texas.

ACCORDING to the Federal Bureau of Entomology and Plant Quarantine, investigations in sterilizing fruit for the Mexican fruitfly have shown that the holding period at 110 degrees F. can be reduced from 8 to 6 hours provided the time for heating the fruit to this temperature is at least 8 hours, making a minimum treating period of 14 hours. The administrative instructions issued as circular P.Q.C.A.-329 on March 3, 1932, were accordingly modified and superseded by the issuance of circular B.E.P.Q.-472 on April 8, which provides for such reduced holding period.

RESERVATIONS FOR ANNUAL MEETING AT RICHMOND, VA.

Early reservation of rooms for the December meeting of the American Association of Economic Entomologists is imperative, owing to the limited accommodations. The Hotel John Marshall in Richmond will be the headquarters of the entomologists. This hotel has the following rooms available:

Number of Rooms	*Prices*
40 single or double	$3.50—5.50
40 single or double	4.00—6.00
20 single or double	5.00—7.00
40 twin beds	6.00
60 twin beds	7.00
50 twin beds	8.00

Reservations should be made through Leonard K. Baber, Director of Advertising and Sales, Richmond Hotels, Richmond, Virginia.